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ABSTRACT

These proceedings were composed of 290 papers, submitted by 700 authors from 15 countries, in the field of rehabilitation engineering and technology. Of the 290 papers, 13 are written in French. Papers are generally two to four pages in length, and are organized within the following areas of rehabilitation technology: service delivery practice (15 papers), personal transportation (3 papers), augmentative and alternative communication (20 papers), prosthetics and orthotics (14 papers), quantitative assessment (30 papers), public policy (4 papers), technology transfer (8 papers), sensory aids (18 papers), wheeled mobility and seating (38 papers), electrical stimulation (23 papers), computer applications (33 papers), rural rehabilitation (5 papers), robotics (11 papers), biomechanics (9 papers), information networking (12 papers), and gerontology (4 papers). Additional papers are presented in the theme areas of education (7 papers), daily living (7 papers), recreation (3 papers), work (9 papers), aging (15 papers), and ethics (2 papers). (JDD)

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ICAARTT '88 would also like to thank everybody and every organization that was still unknown at time of going to press for their collaboration.

ICAART '88 tient également à remercier de leur collaboration, toute personne ou tout organisme qui n'était pas encore identifié au moment d'aller sous presse.

These proceedings of the International Conference of the Association for the Advancement of Rehabilitation Technology represent another milestone in developing the knowledge required to meet the needs of individuals with disabilities. Convening this Third International Conference clearly indicates the strength and dedication of the rehabilitation professionals who are striving to apply the multi-faceted aspects of engineering and technology in the field. The content of these proceedings demonstrate how our knowledge and our ability to implement rehabilitation engineering and technology continues to grow. We are all working hard to assure that there is indeed a Choice for All.

We must also share in congratulating and thanking the many people who made this conference possible; the staff and committee members who developed and implemented this conference and the many speakers and presenters who have contributed to the content. We also congratulate each of you as professionals or interested individuals who have elected to participate in this conference.

These proceedings are comprised of 290 papers submitted by 700 authors from 15 countries. It truly represents a compilation of the international knowledge being applied to meeting the needs of persons in our world who may be assisted through the use of rehabilitation engineering and technology.

We all look forward to coming together again in pursuit of our mission to assure that the future will hold a Choice for All.

Le compte rendu de la Conférence internationale pour le développement de la technologie en réadaptation est un autre jalon dans le développement des connaissances requises pour satisfaire les besoins des personnes qui ont des déficiences. La venue de cette troisième Conférence internationale est une indication claire de la force et de la détermination des professionnels de la réadaptation. Elle vise l'application multifacétaire de l'ingénérie et de la technologie dans le milieu. Le contenu de ce compte rendu démontre comment nos connaissances et notre capacité d'implantation de l'ingénérie et de la technologie en réadaptation continuent sans cesse de croître. Nous oeuvrons dans le but de créer des "Choix pour tous".

Nous remercions et félicitons tous ceux qui ont rendu cette Conférence possible : les permanents et les membres des comités qui ont structuré et réalisé cette Conférence, les conférenciers qui ont contribué à son contenu. Nous voulons aussi féliciter chacun des professionnels et des intéressés qui ont choisi de participer à cette Conférence.

Le compte rendu contient 290 manuscrits soumis par près de 700 auteurs provenant de 15 pays. C'est une véritable compilation internationale des connaissances appliquées en réponse aux besoins des personnes qui s'épanouissent grâce à l'ingénérie de la réadaptation, partout à travers le monde.

Nous attendons cette rencontre qui est la poursuite de notre mission d'assurer que dans le futur, il y aura des "Choix pour tous".

Le président de la Conférence internationale,

Gilbert Drouin
Chairman of the International Conference

Le président RESNA,

C Gerald Warren

C. Gerald Warren
President RESNA

Preface

The watchword of rehabilitation technology has been "independence". Perhaps "choice" would be a better theme. None of us is totally independent and for some of us inter-dependency is an important value within relationships.

A good example is the current emphasis on independent living for our growing elderly population. This surely is a good philosophy provided that community services are properly developed and supported. It is a bad idea if used simply as a means of reducing expenditures on institutional support. I have seen "independence" used as a justification for policies leading to social isolation and poverty.

If I become more disabled through accident, disease or age, then my wish will be to retain my ability to choose where I live, whether I continue to work and what I do for recreation and learning. Rehabilitation technology has the potential of broadening those choices available to me.

The theme of this conference is "choice for all". Thus, this is not just a conference on technology but it is also a conference on ways to deliver technological solutions by means of public policy, the health and social services delivery system, and manufacturing industries. Our concern is not limited to *choice* but includes the availability of choice to *all* in need without restriction of wealth, race, nationality, and nature or cause of disability.

The Special Interest Groups of RESNA have played an increasingly important role as the society grows by preserving the opportunities for members to be closely involved. The organization of this conference and these proceedings reflects that trend. The papers have been reviewed and organized into sessions by each of the 16 Special Interest Groups. The sequence within these proceedings reflects the number designated to the Special Interest Group and the order of presentation of the papers within that group at the conference.

We have continued the tradition of the two previous ICRE Conferences by inviting experts to present somewhat longer papers summarizing the state of the art within their field of interest. The theme sessions selected for this conference fitted the broad categories of education, daily living, recreation, work, aging, and ethics.

Préface

Le sous-entendu de la technologie en réadaptation était "indépendance". Peut-être que "choix" serait un thème plus approprié. Personne n'est complètement indépendant, et pour certain d'entre nous, l'interdépendance est très importante à l'intérieur des relations.

Un bon example de ce phénomène est l'importance qu'on attache actuellement à une vie indépendante pour les personnes âgées dont le nombre croît sans cesse. C'est certainement une bonne philosophie, à condition que les services soient développés et supportés convenablement. Mais cela devient une mauvaise approche lorsqu'on l'utilise simplement pour réduire les dépenses qu'occasionnent le maintient en institution. J'ai vu "l'indépendance" être utilisée pour justifier des politiques qui ont mené à un isolement social et à la pauvreté.

Si un accident, la maladie ou l'âge me rend déficient, alors j'aimerais pouvoir continuer à choisir où je vis, si je continue à travailler, et ce que je fais pour me divertir et m'instruire. La technologie en réadaptation m'offre un plus grand nombre de choix.

Le thème de cette Conférence est "Choix pour tous". Non seulement est-ce une Conférence sur la technologie, mais aussi sur les façons d'implanter des solutions technologiques par l'entremise de politiques publiques, du système de soins et des Services Sociaux, et des industries de fabrication. Nous ne sommes pas seulement préoccupés par les choix, mais aussi par la disponibilité de ces choix pour tous ceux qui en ont besoin, sans aucunes restrictions au niveau des moyens financiers, de la race, de la nationalité et du type et de la cause de la déficience.

"The Special Interest Groups" jouent un rôle de plus en plus important au sein de RESNA, car ils permettent un regroupement des membres au sein d'une société qui devient plus importante chaque année. L'organisation de cette Conférence et de ce compte rendu reflètent cette réalité. Les manuscrits ont été revisés et organisés en session par les 16 "Special Interest Group". L'ordre des sections de ce compte rendu est fait suivant le numéro assigné au "Special Interest Group" et la séquence de présentation suit l'ordre chronologique du déroulement.

Nous avons perpétué la tradition des deux Conférences ICRE précédentes en invitant des experts pour faire des présentations un peu plus longues, qui résument les tout derniers développements de la technologie à l'intérieur de leur champ d'intérêt. Les sessions thématiques choisies pour cette Conférence correspondent aux grandes catégories de l'éducation, de la vie quotidienne, de la récréation, du travail, du vieillissement et des éthiques.

Geoff Fernie,
Program Chairman

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"SPECIAL INTEREST GROUP". 1

Service Delivery Practice
Aide à la vie quotidienne

ICAART 88 - MONTREAL

Focusing on the Needs of the Physically Disabled Adult In Rehabilitation Technology Service Delivery

L. Dolman, PEng, M. Ackermann, BASc, M. Clopton, OTR, J. Fassel, BA, B. Wolfus, PhD
DADA, Designing Aids for Disabled Adults

ABSTRACT

Significant work has been done in the area of rehabilitation technology service delivery, but seldom is the distinction between children and adults fully addressed in delivery methodology. Increasingly complex technologies and applications, in addition to the lack of suitable community-based training programs, place new demands on the training abilities of rehabilitation specialists. Expansion of services to adults must take into consideration the unique learning needs and characteristics of the physically disabled adult. Application of methodology from the growing field of adult education could significantly impact on the success of a technological intervention.

The ensuing discussion provides an exploration of relevant issues and describes their incorporation into a program that evaluates and develops suitable behaviours and skills for the successful intervention of technology in the lives of adults with physical disabilities.

INTRODUCTION

Considerable experience and knowledge in the rehabilitation process, particularly in the area of augmentative communication, has been developed in recent years. Delivery approaches and requisite skills on the part of deliverers have been the focus of recent research. The need for a multidisciplinary or transdisciplinary team approach has been established and evaluated [4][7]. Team members typically include an occupational therapist, rehabilitation engineer, speech pathologist, and often a special educator. Systematic approaches to technological intervention have been developed, and involve at least four components: 1) needs assessment, 2) capabilities assessment, 3) performance trials and training, and, 4) evaluation [4][5].

As a result of funding policies, the majority of research and service programs have been directed towards children. One generation of children has received these services and there is growing recognition of the need for services for persons of all ages, as well as recognition of the need for life-long technological support [1]. Programs aimed at adults will need to address their unique learning needs and characteristics, and these will have implications for the program methodology, and the skills required by team members.

DISCUSSION

Microcomputer-based technological intervention often involves extensive training in a variety of computer applications. Community-based programs that are appropriate for adults with severe disablitites are not readily available in Canada. Training the client in the use of a computer application must often be done by those involved in the assessment of needs and capabilities. The learning characteristics of adults with disabilities must be taken into consideration for these training programs to be effective. The relatively new field of adult education has yet to address the special features of assisting the disabled adult to learn. However, awareness of adult education methodology can be beneficial in program development.

Educational models develop from a base set of assumptions regarding the learning needs and characteristics of the student. Knowles (2) has identified five assumptions regarding the learner that differentiate the adult education approach from that of traditional pedagogy. These concern: self-concept, experience, readiness to learn, orientation to learning and motivation.

Self-concept

Children generally have a self-concept of dependency - an expectation that adults will take responsibility for managing their lives. A natural offshoot of the maturing process is the need to be increasingly self-directed; to be able to make one's own decisions and manage one's life. When people begin to define themselves as adults, they no longer see themselves as full-time recipients of education, instead their self-concept is one of a doer or producer.

Knowles points out that adults have a psychological need to be increasingly self-directed, although they may be dependent in certain temporary situations. Encouraging self-directedness in the learning process will contribute to success in learning. The measure of success for the adult-learner is directly related to the measure of self-directedness and self-reliance gained through education.

Experience

The experience of a child is often not addressed, or is used only as a starting point in the learning process. Adults have a store of experience to be drawn on by themselves and others. Experience plays an important role in identity formulation for the adult, in contrast to the child, whose self-identity is largely defined by external sources.

Readiness to Learn

Adults and children differ in their readiness to learn. Both learn best those things that are necessary for them to know in order to progress from one phase of development to the next. Referred to as 'developmental tasks' [6], in children these are the products primarily of physiological and mental maturity. In adults, however, they are the products primarily of the evolution of social roles.

The physically disabled adult's readiness to learn is initiated by practical goals and social concerns that confront issues around functional ability. The disabled adult shares the common need to fulfil and maintain social roles.

Orientation to Learning

Children see education as a process of acquiring subject-matter, most of which they understand will be useful only at a later time in life. The adult's orientation to learning is problem or performance centered. They see education or skill acquisition as a process of improving their ability to cope with life problems they face in the here and now.

Motivation

Children are often motivated to enter into learning situations by external reinforcers, whereas self-determined needs and incentives contribute more to the adult's learning process.

IMPLICATIONS

Consideration of the motivation factors and learning characteristics of adults could have significant impact on the success of a technological intervention. The environment ought to reflect the adult's need for recognition, respect, and acceptance. Furnishings, equipment and assessment tools should be designed for the adult, and an informal, non-authoritative atmosphere will reinforce their sense of independence and uniqueness. Emphasis ought to be placed on involving the client in a process of self-assessment of ability and needs, with the assessment team acting as facilitator. Once mutually agreed upon objectives have been established, the client is involved in the development of a plan to help meet objectives. Learning activities will include independent study and experiential techniques. Finally, the evaluation phase should be worked out together with the client, and involve learner-collected data validated by team members. The assessment/training program becomes a cyclical process of assessment, performance trials, evaluation and reassessment of needs, initiated and controlled by the client, and facilitated by the assessment team. This results in a strong commitment on the part of the client to both the process and the recommended technological intervention.

APPROACH

DADA has applied the above process elements in its adult assessment program. Assessment and training are conducted in our office or in the client's home or work setting. Attention is paid to creating an appropriate physical and psychological environment that will respond to the individual's need to be treated as an adult. Team members strive to achieve a balance that will encourage an independent, self-evaluative attitude, as well as allow the client to disclose relevant information of a personal nature.

Clients are encouraged to develop their own set of objectives, as well as to determine appropriate means of validation. These are documented in a 'learning contract' between program staff and the client. The learning contract states the objectives, resources and strategies used to meet objectives, evidence of accomplishment, and the criteria used for validating the evidence. Clients are assisted in the formulation of objectives, and are encouraged to include both a content and behavioural component when stating objectives [2]. The resulting phraseology is typically " to develop" or "to evaluate [a behaviour] in [a content area]". Clients find it useful to refer to an available list of behavioural objectives. This list is adopted from Taba [3] and Knowles [2], and includes: knowledge, skills, values and attitudes, interpretation of data, application of facts and logical reasoning. Content areas vary with each client, but often relate to the use of a computer application, communication aid or environmental control unit.

Self-evaluation tools have been developed that allow clients to test their own competency levels, examine the results, and discuss them with the program staff. Validation must be meaningful to the client; considerable resourcefulness results when the client is able to determine and control the process. One client with cerebral palsy, who felt apprehension in showing his computer graphics to friends and assessment staff, stated on his learning contract that reasonable means for validating his competency in this area included presentation of his portfolio to a qualified art instructor. Confidence gained through the program enabled him to follow through with his own plan and obtain an independent and successful evaluation from a qualified source.

CONCLUSION

The successful intervention of technology in the lives of persons with disabilities depends on many factors, many of which we are only beginning to understand. Differentiation of the needs of the child and adult, and application of current methodology from the field of adult education could assist rehabilitation technology service deliverers to better serve their adult clients, and may contribute to the success of the intervention.

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COLLABORATIVE PLANNING:
A MODEL FOR TRAINING OCCUPATIONAL THERAPISTS

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ABSTRACT

The design process for technology is considered as a planning technique. Increased participation in the design of the plan may be anticipated to lead to increased participation in the implementation of the plan. This principle is applied to the training of professionals wherein the design of their educational plan provides a model for the subsequent collaboration with their clients in the planning of the latter's therapy and the use of technology.

THE COLLABORATIVE PLANNING PROCESS

In order to increase the effectiveness of the use of technology, a technique has been developed for collaborative planning with persons with disabilities. The disabled person is provided the maximal opportunity for participation in the definition of the needs, and then the goals to be accomplished. The effectiveness of the planning process itself can be measured by the quality and the quantity of the information generated in the interaction between the professional and the disabled person. One measure is the "relevance" of the goals to the stated needs; another the clarity or "specificity" of the goal statements.

The process by which answers are elicited to the questions as to concerns and goals include three phases: The first is EXPLORATION when, in a brain storming format, there should be an adequate sampling of the range of possible concerns. A range of 3 to 5 possible concerns has generally been adequate. It is then necessary to determine the relative value of each. A "shared weighting" procedure is helpful when several competing needs exist. In this SELECTION phase, 3 points are to be shared between each of the items listed - Item #1 is compared to item #2; item #1 to item #3; item #2 to item #3. Relative priorities are thus established. In the several higher priority areas, goals are then generated which in the 3rd SPECIFICATION phase must meet a 3 point scale of WHAT is to be accomplished, WHERE it is to be accomplished, and TO WHAT DEGREE.

Maximal opportunity for participation is assured by asking the questions of the disabled person as to concerns and goals by starting with an open-ended question ("FREE CHOICE"). If it becomes necessary to provide input in order to carry out any of the phases described above, one could then go down the scale of possible participation one step at a time. The next step would be to offer several suggestions from which the disabled person could choose ("MULTIPLE CHOICE"); then a single recommendation to which the person may agree or disagree("FORCED CHOICE). Although the scale mentions the option of prescribing ("NO CHOICE"), it would be unlikely that the plan would be effective if one needed to resort to telling the person what his goals are to be.

An example of this process is the information generated in an interview with a disabled person concerning the design of the appropriate wheel chair. The lowest level of participation in the exploration phase was "free choice." It was necessary to move to the level of "multiple choice" in the specification phase. Living in a house trailer in a rural area, his concerns were that his chair fit the physical dimensions of the trailer, that his chair not tip forward in the relatively rough terrain around his house, and that he have the option of being able to cross a short stretch of gravel near his house. As an example, the goal he specified in relation to the last concern was to "push my chair across the gravel near my house without getting winded." This statement meets the criteria of specificity in that it describes the action to be accomplished the setting where it is to be done, and some measure of the degree to which it is to be done.

Once the goal has been stated in terms understandable to both the professional and the disabled person, a third question can now be addressed by both. At some time after the initial planning session, it is necessary to review the degree to which the goals have been met. Just as in relation to the definition of the concerns and the goals, the disabled person can now also participate in evaluating the degree to which the goals have been met. Concerns which remain can now be identified and new goals set. The process of goal setting and evaluation is a cyclical one.

The definition of the means or the actual technology by which the goals are to be met generally requires a greater degree of participation by the professional than in the definition of the goals. In many instances, the professional can offer several suggestions ("MULTIPLE CHOICE") as the highest level of participation before then moving to that of recommendation ("FORCED CHOICE"); and prescription ("NO CHOICE") only as a last resort. Optimally at the time of the review the disabled person can then contribute to the modification of the technology to a greater degree than in the initial planning.

TRAINING OF PROFESSIONALS

The training of professionals to work in this format with disabled persons offers an unusual opportunity for the student therapist to learn the procedures in the course of experiencing them. The faculty of the training program can serve as a consultant to the student in a way analogous to the eventual role of the therapist to the disabled person. The student is asked the same questions that he or she will in turn ask their client, goes through the same phases in answering them, and is afforded the same degree of opportunity for answering them now in relation to the issues of making an educational plan for the training in the use of the collaborative planning format. Reported here is the actual data generated in a recent course designed with the aid of entry level students at a graduate school program for occupational therapists.

Definition of goals

A group of 17 entry level students listed 30 needs in the exploration phase in a large group format. Each was then asked to select 3 statements which best expressed their individual concerns, to share 3 points between these items to determine priorities, and then to write a goal statement meeting the criteria of specificity for at least one major concern. 7 composite goals were so generated of which 5 received support from several of the students and will be listed below in order of frequency of selection.

1. Goals be prioritized
2. Time-lines be set for proper review
3. Write patient goals which respect the patient's culture and beliefs.
4. Goals be reimbursable by third party
5. Patient will participate in therapist goals

The faculty also explored their concerns and goals independently of the students. The faculty was particularly concerned that the students learn a structured planning process by which patient input could occur; that the students experience this process rather than merely hear about it; and that the process be put into practice in the clinical setting.

The stated goals of the course reflect the concerns of both the faculty and the students:

I. Carry out exploration of a range of concerns (3-5).
II. Carry out such exploration with maximal participation by the patient.
III. Address both patient and therapist goals with the proponderence of goals arising from the patient.
IV. Prioritize goals with shared weights
V. Goals to be specific meeting 3 point criteria.
VI. Carry out cyclical evaluation and then review of time-lines with modification
VII. Turn in chart notes indicating application in a clincal rotation.

The issues of adequate exploration, specificity and clinical application were perhaps added to those initially suggested by the students. In accordance with the goals of the students, there are goals which arise from the faculty as well. The proponderence of the student goals were incorporated into the program goals; and the majority of the program goals arose from the students.

Course procedures

A 6 hour course has been designed leading to clinical application during the student's 1st rotation. After having carried out several interviews with peers, the student is observed in an interview with a patient.

Course evaluation

In addition to the meeting of the course goals during the observed interview and the chart notes generated during the clinical rotation, the student carries out a self-evaluation before going out on the clinical rotation. He or she will evaluate the degree to which the course goals have been met and develop an individual plan for the clinical rotation. In this way, the student replicates the cyclical planning with the patient.

CONCLUSION

A process of collaborative planning has been described in use with disabled persons. The training of professionals in the use of such a process replicates the activity it describes. The professional is thus enabled to experience within the educational program a model of the activity to be carried out with their clients.

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AN ASSESSMENT PROTOCOL FOR THE SELECTION OF ACCESS SYSTEMS FOR PERSONS WITH PHYSICAL DISABILITIES

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INTRODUCTION

For many individuals with a physical disability, computer-based technology such as communication devices, powered wheelchairs, and environmental controls may provide the only means of attaining independence. However, maximum benefit can be gained from these devices only when the individual has an appropriate access system to control them.

Recently, developments in the rehabilitation field have provided many different means for disabled individuals to access available technology. For example, expanded, miniature, and single-handed chordic keyboards may be used by those who cannot use the standard keyboard. Keyguards, mouthsticks, or headsticks may facilitate the client's control of any type of keyboard. For individuals who are unable to use keyboards, many types of switches and joysticks may be used to select items from a visual keyboard, or to key in morse code. Research is underway to develop new technologies such as eye-gaze or ocular control systems, and voice recognition systems which do not require direct physical contact by the user (9, 11).

PRESENT ASSESSMENT APPROACHES

When only a few options existed, a trial and error method or "trying-on" of access systems was feasible and not impractical (2). With a proliferation of access systems, it is now necessary to systematically and objectively consider options to determine which will best satisfy the user's needs and abilities. Several researchers and clinicians have developed systematic approaches to determine the most appropriate way for a client to control technology. For example, Barker & Cook (1981), Shapero & Kraat (1980), and Wright & Nomura (1985) have developed models for prescribing appropriate input devices such as keyboards and switches. These models do not, however, consider the issues in prescribing appropriate displays of pictures, symbols, and letters for a client. Other models address these issues, but primarily within the context of the prescription of an augmentative communication system (2, 3, 4, 5, 6, 7, 10). No model yet fully considers the client's need to use systems other than communication devices, the need for a more comprehensive assessment protocol arose.

DEVELOPMENT OF A CONTROL ASSESSMENT PROTOCOL

The Control Assessment Protocol (CAP) developed through the combined efforts of the University of Toronto and the Hugh MacMillan Medical Centre, aims to meet this need. In the form of a manual, it provides clinicians with guidelines for determining the most appropriate system for a client to control technology. The CAP addresses the needs of persons who have a primary motor disability such as cerebral palsy, spinal cord injury, amyotrophic lateral sclerosis, or muscular dystrophy. Sensory and cognitive impairments are only considered to the extent to which they co-occur in individuals with motor disabilities.

The control assessment is one aspect of a comprehensive assessment which is intended to investigate the client's needs and abilities in many areas (e.g., medical, communication, mobility, education, vocation, and independent living). These needs and abilities, in turn, determine whether the potential solutions will include the use of technology. Thus, once the comprehensive assessment team has identified the client's needs for technology, the control assessment begins.

There are four unique features of the CAP. First, the CAP may be used to determine the appropriate access system(s) for a client who wishes to control a wide range of technology. In addition, the need for more than just an input device is considered for control. Thus the CAP focuses upon the *access system*, a collection of components and techniques used to interact with the technology. This access system is composed of four components: *input device*, the device by which the client controls the desired target system, e.g., keyboard, switch; *selection set*, the visual, auditory, and/or tactile presentation of available items for selection, e.g., letters, pictures on a keyboard; *selection technique*, the means by which the client chooses items of the selection set, e.g., direct selection, scanning; and *application information*, the output from the target system as it is sent back to the client, e.g., text on the monitor.

Second, a nine-stage framework or structure has been developed to describe the assessment process from the initial referral to the final installation of the system in the client's home community.

The first two stages, *Gather Background Information and Observe the Client*, provide the clinician with static and dynamic "pictures" of the client as a whole person.

In Stages 3 and 4, *Survey Client Skills and Investigate Ideal Access System Characteristics*, the clinician manipulates specified variables to determine the "ideal" access system characteristics for the client.

In Stage 5, *Propose Access System*, available access systems are examined to identify the components the client will use on a trial basis prior to finalizing the decision.

In Stage 6, *Personalize Access System(s)*,the access system components are "tailored" to meet the needs of the client, and integrated with his/her other technologies as well as non-technical strategies.

Instructing the client in the use of the access system is often initiated in the earlier stages, i.e., from Stage 3 to Stage 6. Goals and strategies for training the client are formalized in Stage 7, *Set Goals for Instruction*.

Stage 8, *Implement the System*, includes preparing the client and caregivers for using the access system and target system within the appropriate environments.

Stage 9, *Monitor Progress*, includes guidelines for reviewing the client's use of the access system.

A problem facing a clinician in any assessment is the manipulation of the vast information collected. The third feature of the CAP is related to the decision criteria provided at various stages to help the clinician narrow in on the options that will best meet the client's needs and abilities. Critical issues are highlighted and guidelines are provided for interpreting the information gathered.

Fourth, it is anticipated that the CAP will remain applicable despite the changing technology as the assessment guidelines are presented in terms of general principles. Specific hardware and software are referenced in the CAP as illustrations of these principles.

SUMMARY

Utilizing the systematic approach of the CAP will prepare teams to make well-informed decisions regarding the prescription of and the personalization access systems for individuals. Effective control will thus allow individuals to partcipate more actively in society.

The CAP will be pilot-tested with teams at six centres during the winter of 1988. Funding has been requested for further field-testing with 30 other centres.

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Vocational Rehabilitation Decision Analysis Using the Analytic Hierarchy Process

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INTRODUCTION

Decisions regarding the vocational rehabilitation of specific individuals are quite commonly made by a multi-disciplinary team. The unique nature of each client's vocational rehabilitation may require the perspective of a wide range of disciplines. This team approach offers the benefit of the group's collective knowledge and judgment, but may be limited by the decision making process. The role of each member of the team may be difficult to identify, the factors considered and their relative importance may not be documented, and the role of the consumer may not be well defined. Most vocational rehabilitation decisions also involve the balancing of multiple objectives and multiple constraints. Some formal decision making procedures may have applications for vocational rehabilitation decision making. In particular, the **Analytic Hierarchy Process (AHP)** developed by Saaty (1980) may be an effective tool for decision analysis in the vocational rehabilitation service delivery process. Some of the benefits of this procedure are that it:

1. Documents the factors considered and their relative importance.
2. Incorporates and documents roles of the client and professionals in the process.
3. Combines objective data and subjective evaluation in the same procedure.
4. Provides flexibility to model the unique client-vocation-service delivery-environment mix.
5. Compares alternatives on an interval scale, so that amount of difference is measured.
6. Evaluates sensitivity of differences to changes in subjective evaluations.
7. Measures the consistency of evaluations and significance of comparisons.

ANALYTICAL HIERARCHY PROCESS (AHP)

The AHP approach to decision analysis consists of four basic steps. Each of these steps will be discussed as they relate to vocational rehabilitation decision making.

1. Construct a hierarchy of interrelated decision elements or attributes.
2. Collect input data through pairwise comparisons of decision elements.
3. Use the "eigenvalue" method to estimate the relative weights of decision elements.
4. Aggregate the relative weights of decision elements to arrive at a set of ratings for the decision alternatives.

Decision Hierarchy

The first step in applying AHP is to structure the evaluation process in a hierarchical manner. This structure assumes that there exists several high level independent value attributes. Each of these high level attributes can be decomposed into several lower level attributes. The process of decomposition can be continued until the desired level of detail is achieved. This hierarchical structure can be developed through two fundamentally different processes, **object-driven** and **alternative-driven** value structuring methodologies.

Top-down or objective-driven hierarchy development is used when the decision alternatives under consideration are not well defined and the goals of the decision maker can be clearly described. Global objectives are stated first, then subdivided into objectives and subobjectives until a final set of attributes is obtained. The objective driven approach is well described in the literature, Keeney and Raiffa, 1976. The bottom-up or alternative-driven starts with a reasonable set of alternatives. The major differences among the alternatives are then identified. The differences are then grouped into factors and these factors then used as higher level decision elements. This approach is effective when the alternatives are better defined than the value structure. It focuses attention on the differences among the alternatives and the decision at hand rather than the development of information that may not effect the decision outcome (Buede, 1986).

The alternative-driven methodology is well suited to the vocational rehabilitation decision process. For example, one of two alternative programs (**A** or **B**) is to be selected for a client. The rehabilitation group determined that program cost (**Cost**), the match to the client's capabilities (**Able**), and job satisfaction (**Sat.**) discriminate between the alternative programs.

Pairwise Comparisons

The relative importance (or weight) of each of the decision elements (**Cost, Able, and Sat.**) can be developed through a wide variety of techniques. The AHP approach uses pairwise comparisons as the basis for estimating the relative weights of each of the elements. The pairwise comparison has as its principle advantage its simplicity. Two factors are compared at a time and the difference scored on a nine point scale, with 1 indicating no difference between **A** and B and 9 indicating overwhelming superiority of **A** over **B.** For B superior to **A,** the reciprocal of the **A** to B comparison is used. Attention can be focused on a specific comparison. The interaction of multiple objectives is left to the model to evaluate. The major shortcoming of this method is the number of comparisons that must be made when there are a large number of decision elements.

	Cost	Able	Sat.	EV	W
Cost	1.00	0.33	0.20	0.41	0.09
Able	3.00	1.00	1.00	1.44	0.33
Sat.	5.00	3.00	1.00	2.47	0.57
			Sum	4.31	1.00

Pairwise comparisons can be performed as part of a group process with the resulting score being the consensus of the group, or specific individuals may provide comparisons for their area of expertise. The client may provide comparisons at several specific points in the AHP process or participate in the group process.

Estimate Weights

The geometric mean of the pairwise evaluations is calculated as an estimate of the principle eigenvector (EV). The geometric mean is the N^{th} root of the product of pairwise comparisons in a row, where N is the number of columns. The **EV** vector is normalized to sum to one. These normalized values are estimates of each decision element's relative weight (**W**).

Aggregation

Alternatives are compared on a pairwise basis for each of the lowest level decision elements. The resulting weights for each alternative are multiplied by the weights of the higher level decision elements and summed.

Cost	A	B	EV	W
A	1.00	2.00	1.41	0.67
B	0.50	1.00	0.71	0.33
		Sum	2.12	1.00

Able	A	B	EV	W
A	1.00	0.13	0.35	0.11
B	8.00	1.00	2.83	0.89
		Sum	3.18	1.00

Sat.	A	B	EV	W
A	1.00	5.00	2.24	0.83
B	0.20	1.00	0.45	0.17
		Sum	2.68	1.00

The comparison of alternatives **A** and B uses the hierarchy of attributes developed by the group. The calculations below indicate that **A** (0.58) is preferred to B (0.42). This difference stems to a large degree from the importance of the **Sat.** (0.57) attribute and the difference between the **Sat.** comparison of **A** (0.83) and B (0.17).

Aggregation

	Cost 0.09	Able 0.33	Sat. 0.57	
A	0.67	0.11	0.83	
	0.06	0.04	0.48	0.58
B	0.33	0.89	0.17	
	0.03	0.30	0.10	0.42
			Sum	1.00

Techniques beyond the scope of this paper are available to evaluate the consistency of each table of comparisons (Saaty, 1980) and develop confidence intervals for the aggregated weights (Saaty and Vargas, 1987).

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MULTILEVEL PROJECT STRATEGIES FOR THE DEVELOPMENT OF REHABILITATION DEVICES FOR THE PHYSICALLY DISABLED

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INTRODUCTION

Rehabilitation clinicians working in service delivery settings are often presented with disabled clients for whom commercially available devices are unsuitable. Occasionally, ad hoc adaptations to existing hardware produce satisfactory outcomes, however, usually this approach serves only as a temporary solution. Ideally, to succeed in providing appropriate serviceable technical aids to disabled individuals, service delivery programs require access to clinically-based technical resources which employ structured project strategies to support product development.

Discussed in this paper is a model of project strategies used to support the development of rehabilitation devices through the Mechanical Design and Services Program operating within the Rehabilitation Engineering Department at the Hugh MacMillan Medical Centre.

DISCUSSION

Once a clinical need has been identified, and it has been determined that there is no suitable device available commercially which satisfies this need, then generally one of four project strategies is employed to support the development of a rehabilitation device. These project strategies are categorized as: recoverable client-specific, recoverable group-specific, research-based and renewable service-dedicated.

Recoverable Client-Specific Projects

Requests for client-specific device development principally originate from either service clinicians or private individuals and are on a fee-for-service basis.

Initially, the program coordinator meets with the originator and any others he feels may contribute to the formulation of general design specifications. Based on these specifications a conceptual design is created and an estimate of the development cost is prepared. Following budget approval, the necessary modifications to an existing device are made or a new device is constructed. If necessary, informal in-house trials are conducted with the project participants present, alterations to the device are made, and the device is released for use. Feedback from the originator is encouraged as experience is gained with the dispensed device.

As an example of this, recently the parent of an adolescent with a head injury requested that a manually-driven wheeled mobility device be developed for her child. The adolescent user, the parent, and a seating therapist met with the program coordinator to discuss the details of the proposed device.

Since the disabled user had poor sitting balance, it was important to provide a system which had a secure sitting surface on a "tip-resistant" mobility base. A survey of commercial three-wheelers indicated that they were primarily intended for a much smaller child. As a result, a unique low-level tricycle with a customized seat and adjustable sub-frame was created. Following an initial functional trial with the disabled youth and therapist present, minor modifications were made and the device was dispensed. At the time of writing, the device had been in use for two months with no reported problems.

Recoverable Group-Specific Projects

The complexity of devices created in this category are also varied, however, they are usually geared towards meeting the needs of a particular disability group.

Systems developed by this process typically have low to moderate tooling costs and are low volume items. However, where more than 20-30 devices are to be produced per annum, arrangements can be made for production runs outside the Centre for reasons of time and cost effectiveness.

As part of this project strategy, the initial formulation of the general specifications is usually limited to a small core group of clinicians and designers. Also, the device development proceeds only if the conceptual design appears feasible in terms of production cost and function and will recover development costs from the sale of additional units. Clinical feedback from informal field trials serves as the basis for which design refinements are made.

To illustrate this, clinicians from the Centre's Augmentative Communication Service Department identified the need to develop a mounting system for non-speaking physically disabled persons which would support equipment such as a joystick, a communication aid or a manual graphic display. The system needed to be easily mountable to wheelchairs and provide adjustments which allowed the equipment to be located at specific angles or positions for optimal user accessibility.

Following field trials of an initial prototype system, a production version was created. To date more than thirty "Universal Joystick/Tray Mount Systems" have been sold by the Centre.

Research-Based Projects

Clinical and technical staff often identify significant areas of needed improvements in service delivery practices. If, after a review of existing alternative approaches it is indicated that there is a need to develop a new system, then funding is sought from external sources usually through the preparation of a grant proposal. Included in the proposal are a definition of the problem, a review of existing systems, a discussion of how the presented problem will be resolved through the development of a new system, a justification of method selected and the means by which the success of the developed system will be measured. The proposal is also provided with justified estimates of the project costs and timeline.

Devices developed through this process are usually intended to meet the needs of many disabled individuals in the order of 100+ per annum.

While the coordinator of such a project is typically a program member, the project team will also include clinicians, therapists, technicians, and administrative personnel who have specific roles in ensuring the success of the project.

The conceptual design is reviewed and more detailed requirements are formulated by the project team once funding has been secured. Detailed drawings are prepared and one or more prototypes are fabricated. The arrangement is assessed usually through structured field testing where user, caregiver and clinician comments are solicited in a formalized way. Technical performance of the system is also documented.

As an example, the Centre's Dental and Prosthetic/Orthotics Departments identified the need to develop a helmet which would provide children prone to falls the same level of protection as their custom-moulded helmet but be less expensive to produce and dispense. Through support received from the Hospital for Sick Children Foundation, an industrially-fabricated helmet was developed (Hill et al, 1987). The helmet, which consisted of three parts, permitted the orthotist to achieve a custom fit by adjusting the relative position of the pieces and fastening them in place.

The performance of the helmet was assessed with the assistance of ten individuals who each wore one for two months. Results of the evaluation indicated that the helmet was well-received and could be dispensed economically through the Prosthetics/Orthotics Department, as well as at other Centres.

Further funding has since been secured through the National Health Research and Development Programme of Health and Welfare, Canada to refine the design and develop additional sizes.

Renewable Service-Dedicated Projects

Under this project scheme, support for the development of a "line" of rehabilitation devices for a specific population group is reviewed and renewed on a regular basis by the funding body. Successful developments are contingent on effective interactions of both clinical and technical members of a multidisciplinary team. Continuity of support permits long-term goals to be established so that devices will be developed in a cost-effective and expedient manner.

This process is demonstrated by the operation of the Centre's Powered Upper Extremity Prosthetic Research and Development Program (Mifsud et al, 1986). Through continued support from the Variety Club of Ontario (Tent 28), a range of unique child-size electromechanical hands and elbows has been developed. The development of these devices for upper limb amputees has been very much a multidisciplinary team effort with representatives from mechanical design, the Powered Upper Extremity Prosthetic Services Program, electronics, therapy, social work, production management and administration who attend monthly progress and planning meetings.

These meetings permit service problem areas to be identified and discussed. Once priorities of need have been established, design specifications are formalized and conceptual designs created. Prototypes are developed and tested in the laboratory, as well as through field trials. Production versions are manufactured at the Centre-administered Variety Ability Systems Incorporated. Performance of dispensed devices is monitored through regular service appointments.

To date, over seventy amputees under six years of age have been fitted with myoelectric prostheses.

CONCLUSION

The process of developing technical solutions for clinical-based problems is a systematic one: the problem is defined, design specifications are formulated, a design is proposed, a prototype is fabricated and assessed, if required, the arrangement is modified, and its performance is monitored. However for the design process to succeed, the device to be developed must be supported by the appropriate structured project strategy.

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EQUIPMENT CLINIC SERVICES AT THE SIR DAVID BRAND CENTRE, WESTERN AUSTRALIA

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INTRODUCTION

Western Australia (Pop. approx 1.5 m) is serviced by 5 major seating services which are based in Perth. Similar services exist throughout Australia, however, there is no organised national system. Each service has arisen out of the recognition for the need for specialised adaptive equipment by staff who have then developed specialist skills in the area.

The Sir David Brand Centre is a treatment and training unit for over 250 people with cerebral palsy ranging in age from one to seventy years. Levels of disability range from mild to profound. Other services run by this parent run, government subsidised and charity funded organisation include accommodation, recreation, supported employment and non-vocational options.

The Equipment Clinic at the Sir David Brand Centre is a multi-disciplinary team approach to the provision of equipment. The Clinic prescribes, designs and manufactures equipment for people with cerebral palsy and related disorders receiving services at the Sir David Brand Centre's Infant Treatment area, preschool, nursing and group homes; at community and education support schools; at supported work sites; and in association with a private practitioner O.T. all home needs are catered for. It also acts as a consultancy service to other agencies dealing with disabled and aging populations.

THE EQUIPMENT CLINIC

Staffing

The primary functions of the Clinic Co-ordinators (an occupational therapist, physiotherapist, and engineer) are:
- management of the clinic
- consultancy on client assessment
- equipment design and manufacture
- teaching
- research

The Clinic is supported by technical staff and a fully equipped on-site workshop including an autocad computer for design and documentation of records.

Philosophy

The philosophy of the Clinic is to emphasise positioning as a total regime rather than to provide seating only as an option - hence the name Equipment Clinic rather than seating clinic. This philosophy has been strongly influenced by the work of Diane Ward (1) and Keila Waksvik (2). Total equipment provision is evaluated ranging from positioning devices for all positions, aids to assist functional activities of daily living, and access to technology. Importance is placed on early mobility (3) and children (12 months and over) are routinely introduced to electric mobility devices as appropriate.

Assessment procedure

The Clinic has developed its own comprehensive assessment procedure that incorporates documentation from the initial stages of data collection (e.g. caregivers/clients needs), through posture, movement and functional assessment, therapeutic and technical specifications, to delivery and follow up.

The posture, movement and function section develops a grid system that enables therapists to develop a detailed analysis of posture, movement and function in any one position (e.g. sidelying, sitting, etc.) and also enables evaluation of one component in all positions (e.g. pelvis or head position). The following diagram shows part of the grid system which has been simplified for the purposes of this illustration.

Diag.1: Simplified grid system

Postures	Postural control	Pelvis	Hips	Knees	Feet	Trunk	Shoulder girdle	Arms	Hands and hand func.	Head/neck
Supine										
Prone										
Sidelying										
Sitting										
Standing										
Walking										

The assessment also includes Hobson's classification of group type and technical type (4) for research purposes.

Technology Used

Most adaptive equipment is manufactured on site, but subcontractors are utilised when possible. Seating technology commonly used includes combinations of wood, plastics and foam; the shapeable matrix system, and the Rookwood Bead Seat.

Product Development

The Clinic is actively involved in the design and development of a variety of adapted equipment necessary to meet the specialised needs of clients within the settings seen by the Clinic. These include a prone board, a sidelying board, walkers and standing frames, and a variety of tables, seats, etc. Consultancy is provided to local manufacturers in the development of their products, e.g. a modular electric wheelchair, specialised potty chairs.

Teaching

As well as running a number of small seminars, the Clinic runs a national four day training workshop entitled "Positioning for Function" which is currently the only one in Australia. The Clinic has also developed a resource manual and two videos entitled "Evaluation of Posture, Movement and Function to Determine Therapeutic Positioning and Equipment - A New Assessment" and "Therapeutic Techniques Used in the Manufacture of Adaptive Seating".

Research

The Clinic Co-ordinators have conducted one small research project on the influence on hand and visual skills by the use of a sidelying board. Another research project on seating is underway. It is envisaged that this will become an important function of the Clinic.

CONCLUSION

The Equipment Clinic is still in its early stages of development but the basic management structure and assessment process has been established. There are still significant problems to be faced such as insufficient staff to cope with the workload and hence unacceptable delays in production. Further experience and evaluation of the effectiveness of different techniques is also required. The problem of our geographic isolation is a challenge which requires innovative approaches to overcome. However, the Equipment Clinic Co-ordinators find it stimulating to be able to work within an environment that allows the development of ideas, use of different technologies and provides teaching and research opportunities.

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ON THE ROAD AGAIN: PART II

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ABSTRACT

Although areas with heavy and light populations have similar needs in terms of health care, historically rural regions have had difficulty attracting and keeping qualified rehabilitation personnel. This paper describes Community Services, a private practice providing independence through education, therapy, and technology to individuals of all ages and disabilities in southern Missouri and Illinois.

BACKGROUND

This project is easily replicated as the basis for a private practice...(1); the private practice mentioned was to be initiated by the readers of the paper. However in June of 1987 three months after the proceedings deadline, the author replicated the project as the basis for the beginning of a private practice and Community Services came into being.

Community Services evolved from Community Pediatrics, a program initiated at Washington University in 1979. The original two-fold program was funded through a federal grant that provided both a graduate program in the Program in Occupational Therapy with a concentration in community pediatrics and a service provision program staffed by clinical educators.

At one time four clinicians provided services to 18 community agencies in Illinois and Missouri. With an administrative change in 1984 Community Pediatrics was transferred to the Irene Walter Johnson Institute of Rehabilitation (IWJ), a Washington University clinical component. One contract remained after the original employees elected to enter private practice.

Community Pediatrics slowly added contracts after analyzing service delivery within the community (2). The Systems Skills Assessment (3) and the Community Resource Assessment (4) were used to determine the need and to plan further community services. By August of 1986 eight contracts were being served by three clinicians.

During another administrative change Community Services was returned to the auspices of the Program in Occupational Therapy on December 1, 1986.

The final change occurred in May of 1987. After attempting to dismantle Community Pediatrics, the decision was made to limit service provision to within a 20 mile radius of St. Louis, MO. Four of the eight contracts were notified to locate new service providers.

METHODS

Although a formal advertising campaign has not been conducted, many community agencies desiring educational and therapy services have found Community Services. Service provided to contracts is billed on an hourly basis; mileage is negotiable. Both indirect and direct services are offered. Specific direct services include evaluation, treatment planning, and intervention; education and consultation comprise the indirect services.

To date eight contracts with agencies have been finalized. Requesting direct services were four agencies: a special education district of two counties serving students aged 3-21, a special education district of three counties serving students aged 3-21, a private school serving students aged 3-21 with severe and profound disabilities; and a four county program providing homebound services to newborn to three year old children.

Indirect services in the form of recommending computer systems and providing training to personnel were requested by an agency providing educational opportunities to adults with mental and developmental disabilities; a day training program for adults with severe and profound disabilities, and county program with sheltered workshop for adults and a program for children aged birth to three years. The eighth contract was signed with the Program in Occupational Therapy at Washington University to teach two courses per year: Independent Living Skills I and Independent Living Skills II.

RESULTS

The service provision location varies from agency to agency. For five of the eight contracts the time is spent in a central location. Although there is a central office location in the three other contracts, the service area is not centralized, but is comprised of member schools or homes. Whether the location is centralized or decentralized, each facility provides educational materials and therapeutic equipment as well as desk space, office supplies, telephone access, and photocopying privileges.

Overhead expenses are decreased because neither a practice owned clinic nor a secretary to answer the phone or to type reports has been necessary. An answering machine receives calls in a home office, and report writing has been automated. After several revisions a set of report forms for each agency has been boilerplated on a laptop computer. Reports are generated during evaluation and treatment sessions, thus eliminating the paper and pencil middle step. The reports are printed at each site on a typewriter with a printer interface that is carried in the car trunk.

Added expenses include malpractice insurance, added vehicle insurance and maintenance costs because of excessive mileage, printer fees for business stationery and cards. Although letterhead from each contract may be used for report writing, reports written on the business letterhead serve as future advertisement for services.

CONCLUSIONS

The university program has been demonstrated to be easily replicated to form the basis for a private practice. However, when using the program to broaden the market of a hospital based rehabilitation program, steps must be taken to reduce the overhead expenses so that the program can remain viable in the changing health care system.

ACKNOLEDGEMENTS

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REHABILITATION ENGINEERING SERVICE DELIVERY THROUGH ENGINEERING STUDENT DESIGN PROJECTS

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INTRODUCTION

Adequate resources and cost effective delivery of custom rehabilitation engineering design is a continuing problem. One approach is the use of senior engineering students to design and execute projects under the supervision of engineering faculty and rehabilitation professionals. The focus here is on projects that can be addressed with a modest investment of time, resources and technology. This approach has demonstrated that it can bring effective solutions to the needs of individual clients, provide prototypes of devices for groups of clients, or provide equipment needed in the rehabilitation setting for therapy or education.

ORGANIZATION AND PROCEDURES

The program brings engineering design services to selected facilities of the Texas Department of Mental Health and Mental Retardation (TDMHMR), a governmental agency whose clients include the physically handicapped. These facilites include a resedential unit in Richmond (a small city west of Houston), and a number of out patient facilities centered more-or-less around Houston. These have both child and adult clients with a broad range of disablititles. The engineering teams consist of faculty and students in the Bioengineering Program at Texas A&M University. Undergraduate students elect to participate in the program as part of their required senior engineering design project coursework.

The operational procedure is for members of the engineering team to meet with the staff at a facility to identify design needs meeting our guidelines. The guidelines are that the projects be of reasonable scope with respect to the resources they will require and that there be a strong design component. This rules out major research projects and fabrication projects where the design is already known.

Following preliminary project selections, design team meetings are held between the engineers and the therapists for further problem definition and to outline preliminary approaches. The design team then conducts a further search of the commercial and technical literature for existing approaches. In the absence of a reported and available solution the preliminary design is refined. The design solution is then developed in the form of sketches or rough prototypes for presentation to the staff at the originating facility and initial testing if appropriate. This can be a critical step since the earliar clinical discussion is often vague with respect to the details of the need and the appropriateness of the approach. Following approval the next stage of actual fabrication is completed and the product is then brought to the facility for final evaluation. If necessary further iteration can be undertaken. Commercialization of at least some designs is anticipated and others may be manufacutured in sheltered workshop settings. Publication outlets for all prjects are sought and duplication elsewhere is encouraged.

In addition to the design projects the engineering teams serve as informal counsultants to the staff at the various facilities which has provided the opportunity for them to address a variety of technical questions for which the staffs had no other resource.

PROJECTS

A number of the projects concerned communication devices for environmental and educational purposes for non-verbal and motor limited clients. In general these involved a small menu of items to select from, a variety of switch inputs, and one or more outputs. In each case the menu is easily changed and for working with young children the menu can be expanded from one to several items using pictures or real objects. The objective of this design was to provide a communication tool between child and therapist and to teach the use of switches and picture/object association. Modification of commercial toys to allow use by handicapped children for play, directed stimulation, and training aids has also been done including the modification of an electric car for joy stick opoeration. Other therapy equipment for children has included a portable mini-gym, a walking trainer with visual feedback, floation devices and exercise equipoment for motor limited adults. Wheelchair modifications are another common area of interest. One project was the design of an adjustable wheelchair tray that could accommodate the clients voice synthesizer at a comfortable position and angle. This was integrated with her head wand operated wheelchair joy stick. The tray also proved useful to accommodate an electronic musical keyboard which the client learned to use for recreational and music therapy activities. Success here lead to the development of a computer based music trainer with an overlay which simplifies the appearance and apparent functions of the computer keyboard. Another type of wheelchair tray for use by children includes back lighting for the visually impaired. Positioning and stability problems in wheelchairs have also been addressed.

ADVANTAGES/DISADVANTAGES

This program provides an engineering resource which does not exist on site and would be very difficult to duplicate. Even if a facility could justify its own engineer this individual could not be expected to provide the diverse expertise of a large team of people. Our approach also provides access to the technical resources of the University including mechanical and electronic fabrication. A limitation of the program is a loss of immediacy since the engineers are located at some distance from the rehabilitation settings. Another limitation is that students are sometimes intermittent in their effort and careful selection of student participants and projects, along with close supervision, is necessary to ensure that the desired deliverable end products are achieved. On the other hand the student labor is free and this makes the projects very cost effective. The students involved also develop a deep appreciation of the handicapped and of the personal rewards of rehabilitation engineering. Another benefit to the students from the perspective of engineering education is the nature of define, design, build and deliver projects as opposed to on paper classroom projects.

CONCLUSION

The use of engineering student design projects in the rehabilitation setting has proven to be very effective in meeting needs that can be addressed with modest investments in time and resources. While these projects may not include exotic applications of the most advanced technology, they clearly fill otherwise unmet needs for a large group of client and therapy devices. The relatively short term realization of useful devices is also particularly exciting to the working therapist and to the students.

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COMPUTER ACCESS
AS AN EDUCATIONAL SUPPORT SERVICE

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ABSTRACT

A hands-on Computer Access Lab has been established at CSUN -- where 800 disabled students are enrolled -- with funding in excess of $150,000 from Apple, IBM, the California State Department of Rehabilitation, and CSUN. Computer Access is seen as an educational support service in the same way that readers for the blind, interpreters for the deaf, tutors, and notetakers are regarded as support services.

INTRODUCTION

CSUN's Office of Disabled Student Services conducts one of the world's largest conferences on the subject of computers and the disabled. The annual conference, "Computer Technology/ Special Education/ Rehabilitation," draws an international audience of more than 1,000 persons to the CSUN campus each year. In addition to creating a forum for the sharing of information on new technologies, the Office of Disabled Student Services at CSUN also has grants from NASA and other governmental agencies to help them recruit qualified students with degrees in engineering, computer science, and business. For a time, though CSUN offered a large forum for sharing information about computers, and helped large, governmental agencies recruit computer-literate persons with disabilities, there were few computers available for use by disabled students. Though there are some computers available for general student use, disabled students faced the problems of (a) no special peripherals or software available and/or (b) students were limited to some finite time period on PC's and no special accommodation was possible for disabled students.

INITIATION OF THE COMPUTER ACCESS LAB

Funding was sought from a broad base of potential funding sources. Four different university offices provided cash, equipment, and student assistant help. Apple donated four IIe systems. IBM donated two hard disk systems. The University donated a substantial amount of equipment and more was purchased under grants from the California State Department of Rehabilitation. The Department of Rehabilitation also contributed funds for staff members ("Computer Specialists). In all, the Lab opened with a funding base of about $150,000. Students are welcome to make an appointment with a "Computer Specialist" for initial training, which may be on a one-to -one, or group basis. Then they may reserve workstations on a space available basis.

1. It was decided to have dedicated workstations available for disabled students to eliminate time limitations on computer use. If a student needs five hours to complete an assignment, there usually is no problem. The computers are also made accessible through a variety of peripherals and software appropriate to the needs of the student (visually impaired, mobility impaired, hearing impaired, learning disabled, or with health-related disorders).

2. These include mainframe stations, Apple and IBM PC's; Keynote portable computers; such peripherals as TSI and Ohtsuki braille printers, DECtalk and Echo speech synthesizers, keyboard emulators, voice input devices, print enlargers, and single switch devices; a variety of commerically-available word processing programs and such special programs as Vista, Talking Text Writer, Micro-Interpreter, and Soft Vert.

3. We have employed one full-time professional, and another half-time professional person, each of whom is called a "Computer Specialist for the Disabled." These persons each have joint backgrounds in computers and the disabled, one geared more to the fields of engineering and computers, the other geared more to serving disabled students. Together they make a wonderful combination.

4. The university has an excellent computer science curriculum and students wishing to pursue a career in computers are referred to the School of Engineering and Computer Science. The Lab is seen as an educational support service. As such, it helps students with classroom assignments by training them on word processing, graphics or whatever is needed to provide them with classroom support. In addition, the Lab offers 'computer literacy' and therefore makes students more marketable as they seek employment.

5. The Lab is a resource to CSUN's disabled students, of course. However, rehabilitation counselors are invited to visit for an orientation to computer usage among persons with disabilities. Short-term workshops are held in the Lab for counselors from several districts in and around Los Angeles on a regular basis. In addition, middle managers and Affirmative Action officers from local "high tech" firms visit the lab for orientation and special demonstrations.

6. Data are gathered on each student through scores over time on the CALIP (Computer Aptitude, Literacy, Interest Profile), a test that was developed recently at Claremont College in California.

7. Students who are trained in the Computer Access Lab become their own best advocates. Students are trained by the computer specialist to identify the best combination of hardware, peripherals, and software that will allow them to compete as accountants, biologists, etc. They are then encouraged to be assertive during a job interview and state (a) their disability, (b) the combination of hardware, peripherals and software that works best for them, and (c) its price. In this way, students help employers identify what is needed for "reasonable accommodation" on the job. Usually the price stated for special accommodations is less than an employer had anticipated.

8. The Lab offers engineers manufacturers, and distributors a vehicle to experiment on a large, diverse population of disabled students. About forty vendors exhibit each year at the CSUN conference, "Computer Technology/ Special Education/ Rehabilitation." Many of these are happy to leave state-of-the-art products on permanent loan. Others give demonstrations to blocks of students and leave their products on short-time loan.

9. The Lab lends itself readily to the development of new devices. One such is the "CSUN Key Access Lab," a device created by San Francisco engineer, Neil Scott. Scott's single-switch, keyboard emulator has these characteristics: (1) IBM compatible, (2) interacts with standard software using single action input devices, (3) requires no computer modifications, (4) utilizes a high efficient "cluster" technique in row/column scanning which draws upon the frequency of the occurrence of letters in the alphabet, and (5) physical keyboard remains operational at all times.

10. An important end result of the educational system is employment commensurate with training and ability. The Lab makes disabled students computer-literate and brings employers physically into the Lab to see students work at their stations. What are you doing, how does this work, and how do you see using this on the job are common questions. Through the Lab, students become better employees and employers become more aware of how technology can make a person with a disability an effective employee.

ACKNOWLEDGEMENTS

The Computer Access Lab is supported by the California State Department of Rehabilitation, CSUN, Apple, and IBM.

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THE LIVING AND LEARNING RESOURCE CENTRE

Donna Heiner, Ed.S, Director

INTRODUCTION

Michigan's Living and Learning Resource Centre (LLRC) provides a comprehensive information and demonstration center on the selection, development, and/or adaptation of high-technology for educational and vocational purposes. Focussing on low-incidence populations, the LLRC allows individuals or agencies the opportunity of obtaining information on or previewing adaptive equipment and software.

Located in the Library of the Michigan School for the Blind in Lansing, the LLRC houses a variety of computers, adaptive accessories, and communication devices. The LLRC is a State Initiated Project, Michigan Department of Education, Special Education Services. A Facilities grant from the Michigan Commission for the Blind, Michigan Department of Labor, has made possible a wide assortment of equipment and software specifically designed for individuals with visual impairments.

SERVICES

Investigation of the resources and situation existing in Michigan revealed that a primary need was for information. Although the devices existed and funding was, in many cases, available, the expertise and information necessary for professionals to make decisions about appropriate devices were lacking. Therefore, the LLRC organized to serve as a centralization of local, state, and national resources dealing with similiar populations. The prime focus is to meet needs which are not yet met and to cooperate with and complement other resource already in existence. The purpose of the LLRC is to provide a wide range of services dealing with state-of-the-art information and technical assistance for all individuals with physical disabilities, their service providers and parents, in the evaluation and/or adaptation of devices which will contribute to the normalizaton and integration of individuals with physical impairments.

The following objectives describe the services provided by the LLRC.

The LLRC will evaluate equipment for the handicapped

Because of its accessible, central location in the State, the LLRC is ideally situated for a demonstration center. Its computer room houses an array of voice output communication devices, input and output devices, switches, interfaces, and both specialized and general-purpose software. Because of its vocational component, the Centre includes IBM-PC compatible computers as well as Apple equipment. All computers have speech synthesizers; individual computers are up for use with specialized keyboards.

The LLRC will identify modifications of tools and/or the work environment for individuals with handicaps

Based on output from the multi-agency Agency Oversight Committee, LLRC staff provides information to clients and professionals regarding adaptations to increase the effectiveness of vocational placement. Referrals may come from Vocational Rehabilitation Services, Vocational Education, the Michigan Commission for the Blind, Community Mental Health, present or potential employers, parents, or the individuals themselves.

The LLRC will serve as an information clearinghouse

Because the LLRC functions as a state-wide clearinghouse, requests for information are received in a variety of ways: by phone, conventional mail, electronic mail, or in person. Many inquiries can be answered immediately; however, others may require extensive staff research.

Dissemination of information to professionals, both in the fields of education and rehabilitation, provides another means of sharing information.

As part of its cooperative relationship with Project ACCESS, the LLRC reaches special educators and administrators through the ACCESS Newsletter. The PAM Assistance Centre publishes LLRC publications as part of its PAM REPEATER monograph series.

The LLRC will provide professional development training

The LLRC focuses on both preservice and inservice training. The LLRC serves as a resource to teacher training institutions in Michigan, both as a source of speakers for classes and as a resource/inservice center on computer-related technology. The Department of Counseling, Educational Psychology and Special Education, College of Education, Michigan State University, utilizes the LLRC as a practicum site for graduate students majoring in the field of visual impairment.

The LLRC will conduct diagnostic assessments

LLRC staff consults with parents, individuals, and professionals to provide recommendaitons, technical support, and follow-up on the selection and use of adaptive devices. The majority of consultations involve an individual, parents or caregivers, and a team of professionals.

Because of the cost of adaptive devices and the complex problems of many clients, it was seen as essential to be able to provide short-term loans of equipment for trial use in the individual's environment. The LLRC administers a short-term loan of equipment purchased through a grant to the Physically Impaired Association of Michigan.

CONCLUSION

The LLRC has begun its second year as a state-wide information and demonstration center on special needs high-technology. The above described services are providing parents, individuals with physical disabilities, and professionals in Michigan with the information necessary for them to make knowledgeable decisions about the selection of adaptive technology.

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SERVICE DELIVERY PROGRAM AT GOOD SHEPHERD REHABILITATION HOSPITAL

A CLINICAL MODEL

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INTRODUCTION

The last ten years have seen a significant increase in the number of technical aids available for the handicapped population. However, the general perception among the users and clinical personnel is that technological sophistication is making these devices more complicated to use. Improvement and increased complexity of these aids has generated the need for specialized personnel to recommend, adapt, and instruct users in the appropriate operation of these aids. This combination of technological sophistication and the limited number of experienced personnel in service delivery programs has resulted in a variety of devices inadequately prescribed and supported.

Several models of service delivery programs (SDP) have been implemented (1,2,3), however the criteria for the selection of an appropriate working model are difficult to identify given that different institutions serve distinct populations with particular treatment plans and unique economic and human resources.
In a similar context, rehabilitation technologist training programs are instituted (4) however, there is currently a shortage of experienced personnel.

At Good Shepherd Rehabilitation Hospital we have developed and implemented a multidisciplinary service delivery model based on the existing clinical structure. The model provides the client with sequential evaluations in the different services of the engineering delivery program and develops expertise in the clinical personnel by assigning each team member to only one specific category of technical aids. This model facilitates the training of clinical personnel, and provides the patient and/or attendant with state of the art devices, information and detailed instruction on how to use the devices.
The purpose of this paper is to describe the organization of the clinical model of rehabilitation engineering service delivery program implemented at Good Shepherd Rehabilitation Hospital.

S.D.P. CLINICAL MODEL

There are rehabilitation engineering facilities which focus their services primarily in one category of technical aids (1). At Good Shepherd Rehabilitation Hospital the SDP was organized to provide a complete line of services to our patients and long term care residents.The multidisciplinary service delivery model was organized around a Technical Aids Recommendation Team (TART). The purpose of TART is to provide a mechanism for the recommendation and prescription of assistive devices to referred clients. The team consists of a physiatrist, rehabilitation engineer, occupational, physical and recreational therapists, speech pathologist, and vocational specialist. Access to other clinical services such as nursing, psychology or social service is provided as needed. The service areas provided by the TART are: home evaluation, functional seating, personal mobility, augmentative communications, computer use evaluation and training, environmental control units (ECU's) and accessories configuration, recreational aids, and driving evaluation and training. These services are provided in sequential order. In some cases the services can be combined to satisfy particular client needs, (like using a computer to control augmentative communication equipment and/or environmental control units). Clients have access to all the services but not all clients require all the services. Internally each team member is assigned to a specific disability group and becomes the case coordinator for that group. Also, each member of the team is responsible for the evaluation and recommendation of a particular set of technical aids according to function (Fig 1). Case coordinators conduct the initial evaluations and determine eligibility of the client for the TART services. The appropriate team members conduct an individual in depth study of the patient. Before recommending a particular device, trials with different models are performed in our Technical Aids Demonstration Laboratory (TADL). The equipment of the TADL is updated regularly to provide state of the art technology with detailed instruction on how to use these devices.

Each patient case is reviewed by all team members in a weekly technical aids panel. If commercially available equipment does not satisfy the patient needs, the rehabilitation engineer will consider modifications or customized devices.

The end result of the TART evaluation is a written recommendation to be included in the patient's chart for physician's approval.

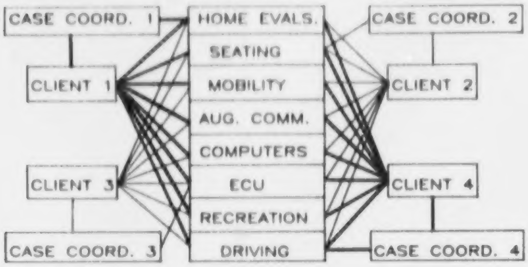

Figure 1

DISCUSSION

The implementation of this service delivery model has been facilitated by adopting well established clinical panel practices. The model attempts to solve two problems: increasing the number of trained personnel with awareness and understanding of device sophistication, while providing an effective service delivery to our clients. Preliminary results suggest that dividing the service delivery process into a series of independent services, and grouping the technical aids by function, facilitates learning and enhances the quality and adequacy of the recommendation process. Thorough understanding of a specific group of devices enhances the information and training provided to the consumer. The sequential organization of the SDP facilitates coordination of different services between different institutions and/or service providers.

CONCLUSION

A multidisciplinary model for rehab. engineering SDP, based in an existing clinical organization is presented. The organization herein described enhances participating personnel knowledge and expertise in the evaluation and recommendation of technical aids for specific purposes and patient populations. The proposed organization promotes further understanding of the functional disabilities of our clients. Further clinical experience is necessary to assess its acceptance among clinical staff members and to assess the effectiveness and quality of the services.

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Playing the Technology Information Management Game
Staying Current : Win ,Lose, or Draw ?

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INTRODUCTION

The increasing rate at which technology is impacting upon rehabilitation service delivery can be as exciting as it is overwhelming. In order to deliver the best possible service to our clients, front line staff and managers must make a tremendous effort to bridge the gap between knowing what is out there and applying that knowledge successfully. Unfortunately, being mere mortals does not help us with all aspects of this process. This article intends to address the problems we have staying current within the rehabilitation technology information management game and proposes some strategies for lessening these problems.

THE NECESSITY OF STAYING CURRENT

The field is changing very quickly. The "**technical evolution**" is influencing service delivery practice, and vice versa. The burden of providing quality care is further weighted by the fact that a solution generated last year may now be considered substandard. The 'standards' for successful technical application keep going up. Many professional associations are appropriately beginning to consider mandatory continuing education programmes.

Not only do we need to understand the technology, we must know how, if , and when to apply it. This process of "**application**" depends directly on our knowledge of the area. Staying current affects our ability to apply technology to meet the unique needs of the physically challenged.

From the experience of the authors, remaining current in rehabilitation technology improves the "**information flow**" between the service delivery providers. For example , in an augmentative communication service, the clinical staff may have difficulty knowing what exists or what is technically possible. Similarly, technical staff who have a "feel" for the technology, may lack the insight to apply devices clinically. In order for the marriage of clinical and technical to work, both groups must strive to stay current, at least in the generalist sense, although it is clear that specialists soon emerge, and are required.

THE HUMAN NATURE OF THE PROBLEM

For our purposes, "information" can be thought of as the transfer of light and sound energy into thought or action that has meaningful implication(s). Information theory defines a "bit" (binary unit) as the amount of information obtained where one of two equally likely alternatives is specified. To illustrate the difference between the magnitude of incoming stimuli and actual storage of the information consider the following: (Steinbuch, 1972)

Process	Max. flow of Information Bit/sec
Sensory Reception	1,000,000,000
Nerve Connections	3,000,000
Consciousness	16
Permanent Storage	0.7

Singleton, (1971) showed that in addition to the relatively slow rate at which information can be permanently stored, humans are also restricted to processing information one channel at a time (limited capacity) and can only discriminate reliably, on average, between 7 different ideas at once.

It may not seem very flattering to think of one's self as being a "single channel limited capacity information processor". The amount of information that can be retained in human memory ranges from (in computerese) 12.5 megabytes to 1,250,000 megabytes, (McCormick, 1976). Although this amount is greater than the storage capacity of any computer, the computer certainly appears to be more orderly in both its storage and retrieval of information. Unlike computers, we are plagued with cognitive overload, confusion, and forgetfulness. Human and external barriers surround our ability to receive, process and act on rehabilitation technology information.

THE BARRIERS

The barriers affecting our ability to make the most efficient use of our information include:
Work load- The usual (health care) emphasis on traditional service delivery can make tasks like reading seem like luxuries.
Time management- Ineffective skills.
Academic training- Possibly inadequate.
Technology- High sophistication and scope.
Personal- The field is changing constantly and this can be stressful and frustrating.
Closemindedness-You don't want to " throw out" concepts/information you just applied.
Details- Too much time for too little value.
Access- Not every source has identified you. You are probably on the mailing list of only a small fraction of the sources who would like you to have their literature.

The barriers must be minimized if we are to maximize the benefit of the information at our command. The degree to which we accomplish this dictates whether we can win, lose, or draw in the information management game.

STRATEGIES FOR PLAYING THE GAME

1. **Incorporating Staying Current into Team Function** - Requires that team members identify and share information. This allows for cross-fertilization of information between technical and clinical staff members.
2. **Time Management** - Need to designate specific priority time to stay current. Develop and priorize a list of "Cando's" per week relating to staying current.
3. **Establish Professional Goals** - To help priorize areas of specialization and generalization. This allows one to pursue details for area of specialization.
4. **Actively pursue information** - Request mailings, talk to vendors, develop contacts, use electronic bulletin boards and data bases.
5. **Be openminded** - Recognize that standards are changing quickly. Be prepared to replace old ideas and innovations with new ones.
6. **Be willing to upgrade academic qualifications** - Through courses, conferences, and regular inservice education sessions.
7. **Develop information storage strategies** - File information using categorization and colour or alphabetical coding.
8. **Develop efficient reading strategies** - Read the table of contents and abstracts before investing time. Be prepared to skim through articles and focus on the discussion section.
9. **Be prepared to share new information.**
10. **Make a commitment** - Realize, and convey to managers / administration that productivity and efficiency depends on staying current !

WHO WINS ?

Staying current has a direct impact on quality care, particularly for advanced level rehabilitation technology services. Relying solely on your existing knowledge base will produce a "draw", and may suffice in the short term. However, the progressive nature of the field will soon turn this into a losing strategy.
Winners of the game maximize the strategies by understanding and minimizing the barriers.

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PROXIMAL STABILIZATION

ALTERNATIVE THERAPY FOR CEREBRAL PALSY

D.G. Kamath, Proximal Stabilization Centre, Surrey, B.C., Canada.

INTRODUCTION:

Majority of Cerebral Palsy Children with Quadriplegia are wheelchair bound, totally dependent and often develop contractures in spite of everything that said and done for them. Proximal Stabilization programme is likely to change it. But it needs to be monitored carefully for long term effects.

BACKGROUND:

Cerebral Palsy is mainly a motor disorder. The children afflicted with it have poor postural security in anti-gravity positions, such as crawling, sitting etc. The Posutral Insecurity is caused by imbalance between the Spastic limbs and the flaccid trunk of the child(1) and fear for safty. Sometimes both neck and trunk are weak among some of them. The imbalance develops due to inability of the trunk muscles to hold the body up-right against gravity. The increased effort by the child results in recruiting muscles of the extremities and tone increases in the large muscles of the limbs(2). The effects of imbalance can be minimized by appropriate support to the trunk or neck and trunk(3).

PRACTICAL CONCIDERATIONS:

All Cerebral Palsy Children may be helped by Proximal Stabilization in future. However, presently some children make better progress than the rest of the subjects.

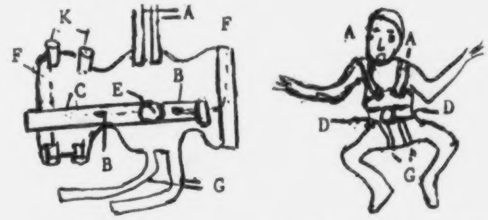
1. Children between the ages of fifteen months to four years of age seems to make significat improvements in their motor skills compare to other age groups.
2. Severely mentally retarded children do not respond to the programme.
3. The programme usually has been success if parents are commited.

PROGRAMME:

1. Orthosis and equipment.
2. Parent training.
3. Follow-up.

The programme is conducted by an experienced Physiotherapist and an Occupational Therapist who pioneered the programme. The children are referred by Physicians.

Orthosis and equipment:- The Commercially available trunk and neck supports are too rigid to allow badly needed movements of the trunk and neck. A flexible trunk orthosis has been designed as illustrated in Fig.1. If neck and trunk needs to be supported a circular inflatable tube is attached to the trunk support in front which support the neck like a collar.

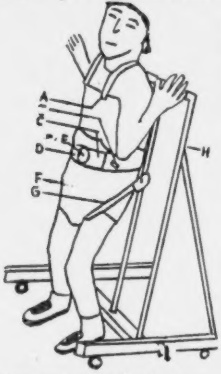


Trunk Orthosis — Child with orthosis

A. Shoulder straps.
B. Bicycle tubes
C. Abdominal Strap.
D. Part of tubes under ribs.
E. Abdominal apperture.
K. Buckles.
F. Velcro Strips.
G. Groin Straps.

Two bicycle inner tubes, each folded in T-shape. Each tube is placed under back velcro strip and the abdominal strap upto the edge of abdominal apperture. The tubes are covered by fiberglass mesh outside and terry cloth inside and shaped as shown in the Fig.1. On the child support is held by shoulder and groin straps and the back velcro strips. When inflated; at 7 to 8psi. the tubes support the sagging trunk, along the spine and under the ribs. The fig.2. shows the orthosis on the child.

Ambulator is the other equipment the child needs. It has rectangular wooden base mounted on 1" casters in the back and one and half inch casters in front.The body of the ambulator is made out of half inch PVC pipe. It has rectangular front and the triangular sides. The pipe is heat moulded. Front is covered by fiberglass mesh. The child leans against it while standing as shown in fig.3. The back end of the base which has rubber pads, digs in the floor and ambulator is stable in this position.Hence the leaning child is safe.



G.Ambulator groin Strap.
H.Body of the ambulator
I.Base of ambulator.
A.Shoulder strapes of orthosis.
B. Bike tube.
C.Fiberglass mesh of orthosis.
D. Abdominal strap of orthosis.

Fig.3 Ambulator.

Parent Training:- Before Commencing parent training programme, child is assessed for his functional level and equipment needs. Assessment and the planned programme is discussed with parent, with special emphasis on the role of the parent in the programme. Because the parent has to conduct the programme after training. It is important that the parent understand the programme correctly, try it out at home and provide the feedback. The training includes:

- how to put the support on the child, the air pressure to be maintained in tubes and precautions to be observed.
- how to monitor the effects of therapy, orthosis and ambulator.
- how to advance the child, and achieve quality movements.

Usual steps to improve postural security are:
1. Instead of chair use ambulator seat.
2. Consistant use of the seat for play, likely to get the child accustom to it. Hence fear for safty is reduced.
3. Child is encouraged to stand with total extention. He is helped to put the weight on feet, while standing.
4. Improving weight bearing on feet by play in standing position.
5. Feet are used while sitting on ambulator seat to move forward.
6. Achieving change of direction of ambulator movements and speed control without external help,likely to make the child confident in maintaining the balance on a moving object.
7. When fear of fall is minimized by better balance and ability to control movements, the child is encouraged to stand and take steps. The seat is removed; replaced by groin straps.
8. Lastly, an adult supports the child from behind, instead of ambulator. Gradually,the helper decreases assisstance, the child eventually becomes independent walker.

Follow-up:- Entire programme takes 10 to 18 months and provided free of cost to Cerebral Palsy victims and their parents. Depending on their individual needs the parents make arrangements to treat their children at home and bring them to the centre to review the progress. During review most of the time has been devoted to advicing the parents how to advance their children. Also to upgrade the orthosis and ambulator to meet continually changing needs of these children.

CASE STUDIES:

Seven Cerebral Palsy Children were referred to the programme. Among them four are less than four years of age. The other three children are between seven and thirteen years of age. All are Quadriplegics. Thirteen year old boy gained head righting ability. The other two from the second group did not improve due to severe retardation. Three younger children achieved ability to walk independently. One child discontinued programme early.

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THE EVOLUTION OF A CHAIR DESIGN FOR DISABLED CHILDREN: AN EXAMPLE OF REHAB. ENGINEERING

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CURATIVE REHABILITATION CENTER

ABSTRACT

A chair design is followed from an initial concept, through custom fabrication for individuals, and into a low-volume production design. Design details are presented along with a discussion of approaches to service delivery.

INTRODUCTION

Providing seating or positioning devices for physically disabled children is a real challenge for chair designers because of variety of needs expressed by rehab. professionals (See Ref. 1). They might vary from a small addition to a regular chair (such as a pad or strap) to a custom chair with extensive additions that might include:

- a contoured seat
- trunk supports
- arm, leg, and foot support
- several straps to maintain position
- head support
- a working surface (tray or table)
- adjustable seat-back angle

In addition to meeting the child's needs, the child will also grow, and their needs might change with time. A good chair design should be able to accommodate growth and changing needs.

THE ROLE OF CHAIR MANUFACTURERS

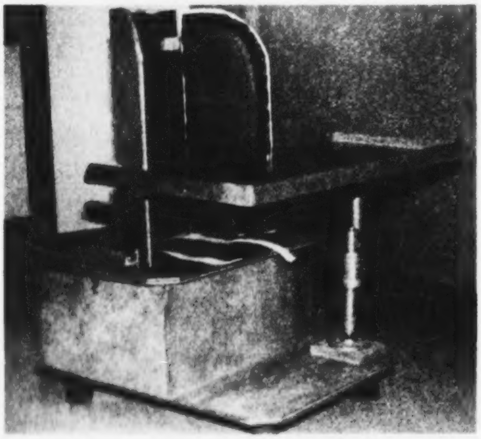
There are several commercial suppliers of seating and positioning devices for children. In order to reach a significant market, their designs are characterized by extensive adjustability and a variety of add-on optional features designed to meet other needs. Unfortunately, disabled children can be so unique that these commercial chairs do not meet their needs, or perhaps, do not meet some conflicting needs.

THE ROLE OF REHAB. ENGINEERING

When a facility has a Rehab. Engineering function in place, the first role is to modify commercial devices so that they meet the special user needs. These may be minor adaptations, but they can be as complex as desired. The second role is to design and fabricate unique devices specifically for an individual. The Rehab. Engineer is often put in other roles as well, and the following description of the evolution of a chair design demonstrates some of these roles.

Developing Ideas

The chair design started with 3 students at Marquette University in Milwaukee, WI doing a Student Design Project (Ref. 2). They wanted to design a simple chair that parents or volunteers could make for disabled children. They used 1/2" plywood and had an interesting "wing-back" design. Curative was given a set of these plans, and assembled a unit for evaluation. The Physical Therapists who tried it like the wing-back feature especially, but asked for another demonstration unit but with a variety of changes. Rehab. Engineering worked up a new design to incorporate these features and made up a new sample for the therapists to evaluate (Figure 1).



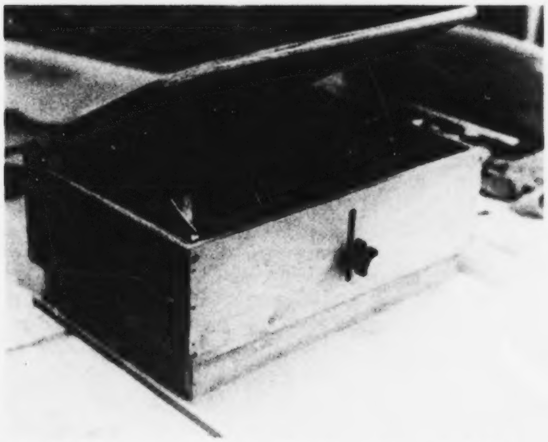
Custom Built Wing-Back Chair

Custom Variations to a Design

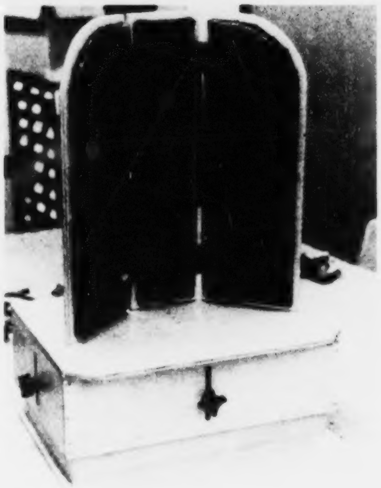
When the therapists found that a chair worked well for a child, they would order one. It was not usually a case of ordering a duplicate of the sample; the therapist wanted certain special features added, or different key dimensions to better fit the child. Each chair was custom built for the end user, but following a rather general design guide; the final chairs looked similar but were actually each unique.

Low Volume or Semi-Production

After a quantity of chairs were produced, some trends became apparent. Some were requested with an "H" harness, or foot supports, or other items that could be considered as an "option" to the chair. Most were requested with casters on the base, with a standard tray, with a 5" wide center-back piece, and within a range of dimensions for seat height, back height, seat length, etc. The design was changed to be more readily adjustable (for instance, seat height can be easily set from 6" to 10", (see Figures 2 & 3) so that one design allows for making up the individual pieces in quantity (and at a much lower cost since the set-up time is about the same whether you make one piece or ten). The chair is not assembled until the order is received; any variations from the standard design are noted, changes made either by making new parts or by recutting the standard parts, and then the parts are assembled. This approach gives some of the advantages of a production unit while maintaining much of the flexibility of a custom design.



Semi-production Chair Showing Seat Height Adjustment



Front View of Semi-Production Chair

Full Production

The chair design has not gone to full production, but this is being considered at this time.

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APPROACHING ON SITE PROVISION OF ADAPTIVE EQUIPMENT AS AN "INDUSTRY": A BRIEF ELEVEN YEAR RETROSPECTIVE

Charles F. Radville, BID. Mitchell F. Komisar, BID.

Wrentham State School, a Massachusetts residential facility for people with multiple disabilities, has for eleven years relied on its adaptive equipment program, Alternative Design, to meet the challenges of mobility, positioning and access to daily living presented by the special needs population. In the mid 1970's, through the actions of parents, relatives and friends of the disabled, a major emphasis was placed on addressing these needs. To accomplish this any skilled hands went to work, cutting foam, plywood and fabrics. Anything available on wheels was put into service as a mobility device to get people up and moving. Materials were begged, borrowed and bartered. Wheelchairs, gurneys, stretchers and geri chairs were repaired and recycled. The creativity of skilled personnel was pushed to its limit.

The initial service, barely formalized, was deluged with requests. Marginal advances in staffing and funding did little to decrease the list of needs or completely satisfy complex problems presented by the clinicians. The approach was planar, utilizing straight backs, seats and positioning pads. Major deformity was accommodated by cutouts and carving. Commercial items which addressed the complex needs of the multiply handicapped individual in an institutional setting did not exist. 'Adaptive' seating systems were overloaded with adjustments, difficult to clean and maintain, and gave marginal results with the target population. It was our goal then, to develop and finish individualized products on site, working closely with a multidisciplinary clinical team. Completion time was a factor in the evaluation of this approach; and had the individual crafting of seating devices been the accepted method, few needs could have been realized in the past years. In realization of this, and due to campaigning by dedicated individuals working at all Massachusetts state facilities for disabled people, administrators began to seek design professionals to provide adaptive equipment. Industrial Designers were commonly hired to draw on their ecclectic background in product development, problem solving and technical skill.

The initial movement to professionalize the field gained added support as the decade ended with the release of salaried positions to encourage recruitment of additional professionals. There was established a budget sizeable enough to upgrade the "craft shop" to a full fledged engineering and development facility. Experimentation was now possible on a large scale and new materials were researched, ordered and tested for strength and durability. Steels, aluminum and engineering themoplastics (i.e. acetal, nylon) were machined and formed to replace the assorted hardware store mechanisms used in the early days. Plywood was discarded in favor of rigid plastic sheet, easy to cut, unnecessary to finish, and hygienic. Machinery which gave repeatable results in reduced time inspired another change: standardization.

Scaling our client base to budget and staff could not economically justify manufacture in large numbers. However, simply designing and engineering components to standard sizes and tolerances would reduce the need for repeated measurement, set up or testing of mechanisms and increase turn over in production. A single manufacturer's stock wheelchair (Invacare's Rolls Model 900 full recliner) was selected to further simplify our service delivery. This would standardize the method of interface as well as the maintenance of both the customized and commercial components of our positioning and mobility system. Combined, these elements gave the ability to mobilize the major percentage of people we serve. The few exceptions (2-3%), due largely to major fixed deformity, use adapted components of the same system interfaced with a self propelled stretcher and require special engineering which could not have been accomplished with previous time and technical constraints.

During this period of development, we were constantly aware of our status as neophytes in a young field, drawing on early publications out of centers from Minnesota to Tennessee. The project with which we involved ourselves came with no users manual or blue print and required the condensation and evaluation of a variety of technical and clinical concepts.

Initially, the approach to seating was to apply as many linear elements as possible to support or control the individual's body. As time progressed we were asked to match or accommodate more complex anatomical contours. This lead back toward more custom design and fabrication of mechanisms to locate and adjust supports. Contoured surfaces were hand carved and formed. This was time consuming and the products were more akin to early commercial systems in their reliability. A better approach was needed. As our major priority and assignment was mobility and positioning, we could allow ourselves the investment in time and resources to revamp the approach to seating. We selected the most common and versatile: the vacuum dilated bean bag. From the start we have, without exception, worked the seat and back as separate elements. This gives us an added dynamic often needed in positioning people with the molded forms. A loose bean bag is the other application accepted for constant use. While indexing the finished forms presents some unique problems, there is an advantage of complete control of the bag's function and contact. The forms themselves are constructed of ½" of Aliplast 4E flexible polyethylene foam (Alimed, Boston, MA) vacuum formed over a plaster impression of the bean bag. The Aliplast is then backed up by 2½ lb./ft. 3 rigid urethane applied as a two part blown resin in a closed box. This approach gives a block shape with a solid back behind the contoured surface, allowing additional trimming at the seating clinic. The form never has padding added, as this detracts from the contours formed on the body.

The forms are finished off with an integral cover of Uniroyal naugaform and sealed and gasketed with a backing plate of Fiberesin (a paper/phenolic sheet material). Fitted terry cloth covers are provided to allow air circulation and to absorb perspiration. The same technology is now used to finish off standard cushions and pads. This eliminates seams and further reduces production time.

Throughout the clinical fittings, the forms are aligned on a tubular stainless steel frame developed and produced by Alternative Design. Features include an articulated back to seat angle and standardized attachment points. The entire assembly can be tilted in space as well, owing to use of the unique design of the Rolls reclining wheelchair. Once angles and locations are approved, a fixed angle frame is fabricated and installed on the individual's wheelchair. The standard attachment points ensure accurate reproduction of settings at the final clinic. Installation in the Rolls recliner allows alternation in functional positions and ease in initial seating and transfer of the individual. Additional features of the seating frame include standard attachments and adjusting hardware for headrests; work, meal or support surfaces; and leg rests. All parts are easily locked, adjustable or removeable as requested.

The seating system is augmented by use of a custom formed chest piece fabricated from Aliplast and Naugaform with identical technology. The 'bean bag' sees additional use in the provision of alternate positioning devices; in side, prone, and supine and post-surgical support and stabilization, headrests and leg and foot orthoses.

In addition to seating and mobility, Alternative Design provides consultation, design, development and fabrication in powered mobility, augmentive communication, vocational fixtures and worksite adaptations, aids for daily living and recreation, and devices used in behavior modification and management. Clinicians in the applicable fields provide initial input and ongoing review during all projects.

It is obviously possible to provide such a service at a local level with the proper approach and with administrative support. Alternative Design is managed and equipped as a technical support and engineering service consulting to clinicians. The physical plant is capable of metal, plastic and wood working (milling, turning, forming and shaping), TIG welding (stainless steel and aluminum), thermoforming and vacuum thermoforming, upholstery and measuring and fabricating to general tolerances of ±.001".

In summary, there has been a steady, longstanding commitment by the Commonwealth of Massachusetts and the Administration of Wrentham State School to support this industrialized approach to the provision of adaptive equipment. This limits the reliance on volunteer or home-craft service that, due to finance or philosophy, is the approach followed in many facilities. The ultimate value in pursuing this model is maximized quality, productivity and clinical effectiveness.

Alternative Design
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"SPECIAL INTEREST GROUP". 2

Personal Transportation
Transport

ICAART 88 - MONTREAL

DIRECTIONS FOR ADAPTIVE DRIVING DEVICE ASSESSMENT

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Louisiana Tech University

Abstract

As the Rehabilitation Engineering Center for Personal Licensed Vehicles for the National Institute for Disability Research and Rehabilitation, Louisiana Tech University has developed standard procedures, assessments, and tools for determining driving ability of an individual. Physical strength and range of motion as well as cognitive and perceptual parameters are assessed. The techniques for accomplishing this evaluation have been described and reported elsewhere[1,2]. Objective functional information about the adaptive driving equipment would also be useful. This paper presents the most important of this information based on our experience in driver assessment, evaluation, and prescription and on preliminary construction of an expert system for prescription of adaptive driving equipment.

Introduction

Various groups, such as the Society of Automotive Engineers Subcommittee on Adaptive Driving Devices, a number of state rehabilitation service agencies, and the Mobility Equipment Manufacturers Association, are in various stages of developing standards for performance and safety of adaptive driving devices. These standards address durability, long-term performance, quality, safety, and (in some cases) installation. The Veteran's Administration was among the first to study these parameters[3]. Very little objective, quantitative information exists about the functional operation requirements of these devices[4]. No standards exist for the acquisition and reporting of information regarding disabled driver capabilities or for adaptive device characteristics. Some device parameters may be given by the manufacturer, but no standard reporting or testing procedures exist for obtaining this information. On the other hand, professional driver educators have very well-qualified subjective measures of this information and use this information regularly. The goal of this work is to identify and capture that information in a reusable form and to suggest how the information might be quantified.

Methodology

The approach taken here emphasizes one of the advantages of expert system building: formalization and clarification of knowledge. Through interaction between local experts (occupational therapist, driver educator) and a knowledge engineer, this information may be elicited and formalized. Tools used to facilitate these interviews were a commercially available expert system development tool (M.1 from Teknowledge), driver assessment data from 30 previously assessed persons with disabilities, a common personal computer (IBM PC\AT), and a common database software package (Lotus 1-2-3). The driving professionals explained their reasoning behind each prescription. The knowledge engineer noted how the client information was used or not used. As the database grew to 30 clients, the critical information was identified. Periodic reviews clarified misunderstandings and pointed to additional information that could prove useful. The database contains 5 prescriptive parameters, 22 physical function parameters, 4 driver strength measurements, 2 sensory parameters, etiology, name, and comments.

The final device prescription contains many components including:
1. vehicle entry (door type, automatic door/lift control, wheelchair lift, and door opening),
2. driver position,
3. steering system (steering effort, steering column modification, steering wheel size, steering device),
4. braking/accelerator control (braking effort, hand control, and others), and
5. secondary controls (ignition, gear selector, parking brake, turn signals, horn, headlight dimmer switch, and other accessory controls).

The most critical of these were chosen as the initial prescription parameters for consideration by the expert system to be developed. These are:
1. steering effort (standard, reduced zero),

2. steering device (spinner knob, tri-pin, quad cuff),
3. steering hand,
4. braking/accelerator effort (standard power, reduced effort), and
5. braking/accelerator device (push/right-angle, push/pull, floor-mounted quad control, foot controls, joystick).

These parameters are considered to be the output of the expert system.

The client data files contain many items of information. Those found to be most directly related to prescription of primary controls were the active range of motion for the shoulder, elbow, forearm, wrist, and fingers of each arm and the manual muscle test for these same locations. Active range of motion and manual muscle test for the lower extremities were lumped together as one parameter. Each item was rated as either within normal limits or below normal limits. The driver strength measurements were taken using the Functional Strength Analyzer, developed by the Center[1,2]. From this set of data, only the minimum strength value for each hand was recorded for both steering and braking configurations. The two sensory parameters recorded were vision and hearing (within or below limits).

Device Information Needed

From the development of this prototype expert system, the following quantitative information regarding adaptive driving devices appears to be important but, as yet unavailable:

1. Maximum force required for braking/acceleration control:
   Under what vehicle control conditions is the greatest amount of force required for braking and acceleration? What capabilities must the client possess in order to operate a particular device under these conditions?
2. The gain/loss of effort produced by the control device:
   In other words, how much force is required to operate the brake and accelerator with the control device as compared to the force required to operate the pedals in a standard manner?
3. Amount of travel of the device in its directions of operation:
   How far must the device travel or reach to fully depress the brake and accelerator pedals? This would be important for quantitatively matching a client's available range of motion in the specific direction of a control devices's operation.
4. Standard mounting position:
   What are the mounting position requirements as stated by the manufacturer? How do these differ among vehicles?
5. Right versus left side mounting:
   How does effort differ between left and right side operation?

Acknowledgments

This work was supported by a cooperative agreement (G0083C0097) from the National Institute for Disability Research and Rehabilitation of the U. S. Department of Education.

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A MULTI-FUNCTION VEHICULAR INTERFACE UNIT FOR QUADRIPLEGIC DRIVERS

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ABSTRACT

Driving allows the severely disabled person control over some aspects of his life and provides opportunities for job training, employment, recreation and increased social interaction. Considerable research and development efforts have been made to provide servo-assisted primary driving controls (brake, accelerator and steering) for the quadriplegic driver while less has been done to provide the driver with access to the secondary vehicular controls in dynamic driving conditions. This paper describes the development of a multi-function vehicular interface unit enabling quadriplegic drivers to access 54 priorized secondary functions through controlling a minimum of three interface input switches.

INTRODUCTION

The provision of custom positioned, servo-assisted primary driving controls normally accommodates drivers with limited force output, limited range of movement or a combination of both from their upper extremities. The spinal cord injured quadriplegic may additionally require hand and/or wrist orthoses in order to more effectively interact with the control system. The primary controls are aptly named as being of primary importance in the operation of a motor vehicle. Priorized secondary controls, from most immediate to least immediate access requirements, would place turn signals high on the list and door/lift controls low on the list. The quadriplegic driver may not safely be able to release any of the primary controls in order to activate one of the secondary controls, such as turn signals, while the vehicle is in motion. The operation of secondary controls requiring nearly immediate action when the vehicle is moving must be performed through body movements which do not compromise control of primary vehicle functions. Secondary controls are usually interfaced through switches activated by other reliable body movements such as elbow, shoulder and head movements. The number of switch sites that can be discriminated is dependent on the particular driver's physical limitations but it would be unusual to find sufficient body movements to provide direct access to all the vehicle's secondary controls while driving. Direct access to the secondary controls is often compromised by the number of body sites available and is normally limited to only a few most immediate functions. Other methods of control are therefore required to augment the number of available switch sites and provide the most direct access to the most immediate secondary controls.

METHODOLOGY

A meeting was held with a local custom equipment vendor, disabled drivers currently driving modified vans with adapted secondary controls, a Hugh MacMillan Medical Centre (HMMC) occupational therapist from the Driver Education Programme, a HMMC driving instructor and representatives from the HMMC Rehabilitation Engineering Department. The goal of the meeting was to determine the motor vehicle secondary functions to be controlled, which of these functions must be controlled while the vehicle is moving and to priorize the list of secondary control functions from most immediate to least immediate use. The secondary controls were priorized in a list of most immediate to least immediate activation requirements in order to provide more direct access to those functions which were given higher priority. The secondary control functions were then grouped into logical blocks for easier access, eg. all heater controls in the same block. The disabled drivers provided information regarding the limitations of and concerns with their current systems and outlined a wish list for the ideal system. The clinicians identified that a potential driver must be capable of operating a minimum of three secondary control switches, in addition to the primary controls, to be considered for interfacing to a motor vehicle.

The logistics of the system's operation were based on a minimum of three interface input switches and secondary functions grouped and blocked to allow these switches to directly select functions in a particular block. There are a total of 17 blocks of functions. A scanning routine was developed to sequentially step through the various blocks. The scanning rate is adjustable from 0.3 to 3.0 seconds per block step and each step produces an optional auditory tone proportional in length to the selected scan rate. To give some form of correlation between a body movement activating the switch and the resulting action displayed on the control panel, the three interface input switches were visualized as S1 requiring a left movement, S2 requiring a right movement and S3 as a "don't care" movement. Left movements correspond to Left or Up display changes in the control panel (ie. left turn signal) and right movements correspond to Right or Down display changes (ie. right turn signal). The third switch (S3) performs a dual function in most of the blocks. A short activation of S3 selects a function in the current block while a push and hold causes the block scanning routine to commence. The three user switch inputs are provided on a separate 9 pin "D" connector, connected in the TRACE Interconnection format.

The prototype control panel houses the microprocessor control circuitry and provides incandescent lamp displays for indicating each function status (green) and the current selected function block (yellow). Most of the disabled drivers surveyed had some form of control console for secondary controls which they were able to directly select when the vehicle was stopped. Others had switches scattered throughout the driving compartment. In order to accommodate both situations the prototype control panel uses dual lamp/legend momentary push button switches and lower cost lamp/legend display-only equivalents. This should reduce the cost of the panel for those drivers not able to make direct selections on the panel and therefore only requiring displays. Blocks of functions not required for specific drivers can be "switched out" on the microprocessor circuit board and the associated switches/displays omitted from the panel to further reduce cost. Connections to each of the 54 panel switches are paralleled to two connectors on the control panel which allow external switches to be connected for custom fitting of direct function control switches in addition to the three main user control switches. For assessment purposes a miniature version of the control panel was constructed with 1/8" jacks at each of the 54 corresponding panel switch positions. This facilitates rapid connection of switches for direct access of secondary controls and allows the therapist to quickly determine appropriate switch type and position. A similar box was constructed providing three 1/8" jacks for rapid connection of the switches used in the scanning method of secondary control selection. All user input switches are momentary contact which the microprocessor interprets as momentary or alternate action depending on the function being controlled.

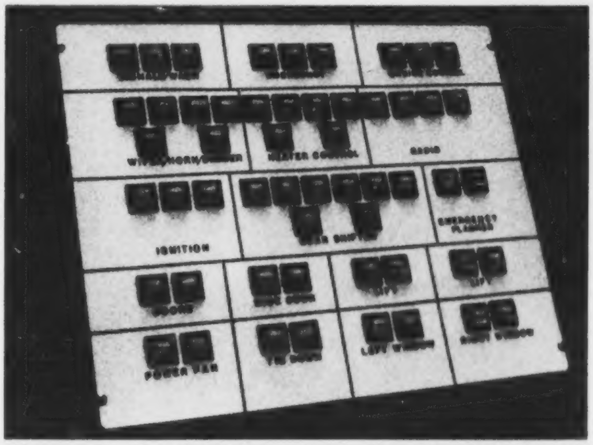

Figure 1: The Prototype Secondary Control Panel

Power MOSFET "H" bridges and High Side driver circuitry were developed for high current vehicle function controls such as heaters and power windows. Power relay control is optionally available for those functions which are neither grounded nor connected to the vehicle's battery positive.

CONCLUSIONS

The prototype control panel is presently undergoing bench testing prior to its installation in the Driver Education Programme assessment room where it will be used under simulated driving conditions. In the future we hope to transform the wire-wrap circuitry into dedicated printed circuit boards that need to withstand vibration and wide temperature ranges encountered in normal vehicle operation. The system has been design to accept a wide range of switch inputs for direct selection of up to 54 secondary controls identified during this project. While these switch inputs are normally momentary electromechanical switches this does not preclude the system from operating with more elaborate switching controls techniques such as the KEMPF voice recognition system without hardware modifications.

ACKNOWLEDGMENTS

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A GRAPHIC METHOD FOR PERSONAL VEHICLE ADAPTATION

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ABSTRACT

A graphic method to assist prescription of adaptive driving devices for vans is described. Up to three views of vehicle controls are overlaid with quantitative client data. The resulting displays of three-dimensional relationships are helpful in visualizing the complex interactions between driver and controls.

INTRODUCTION

Because of its capabilities to accommodate a driver's wheelchair, an adapted/modified van is sometimes the only vehicle that can meet the needs of a disabled driver. The driver candidate's usable ranges of arm motion along with other information are used to determine the types and positions of adaptive driving devices. Wheelchair size and certain points on the body are used to place the driver's eyes at the proper level and to assure adequate clearances. The prescription process can be quite complex.

The driver evaluator's task can be simplified by quantitative data on candidate geometry and on ranges of motion. The current paper describes displays of driver-candidate and vehicle-control data for use by the evaluator.

APPROACH/METHODS

Subject data were obtained with a digital motion analyzer used routinely in driver assessment (1,2). The device provides x-y-z positions in space with a resolution better than 0.1 inch. Driver-candidate subjects were seated in their own wheelchairs; subjects with no physical impairment, in an Everest and Jennings Universal manual wheelchair. Stationary points included top of the head, bridge of nose, shoulder joints, knees, and tips of big toes. Various active movements of shoulder, wrist, and elbow joints were also recorded. Collected with menu-driven Microsoft C software on an IBM PC/XT microcomputer, data were stored on floppy disk for later reference.

Vehicle control and structure x-y-z locations were determined to the nearest 0.1 inch for an 1986 Ford Club Wagon. Y-z coordinates and design location for eyes were derived from a scale drawing of a Ford E150 van (3). The rectangular coordinate systems were similar. Lateral (right-left) distance x was measured from subject midline or from center of steering wheel. Longitudinal (front-rear) distance y was measured from a plane in front of the subject or behind front axle. Vertical distance z was measured from laboratory floor or above front axle.

For results shown in this paper, Sigma-Plot^{TM} software (Jandel Scientific) on an IBM PC/AT was used to plot data on an HP Laserjet printer. Subject data were read from motion analyzer disk files. A similar file for vehicle data was created by keyboard entry. In some cases, data were first rearranged in 123^{TM} spreadsheets (Lotus Development Corp.).

RESULTS

Front and side views of representative controls and design location for driver's eyes are shown in Figure 1. The vehicle floor (not shown) is at about z = 9.5. The top view is not shown due to space limitations. Letter designations are as follows:

BR	Brake Release	IG	Ignition	T	Turn Signal
G	Gear Lever	LT	Lighter	W	Wipers
H	Hazard Signal	M	Mirror	REF	Reference (eyes)
HL	Headlights	R	Radio		
HT	Heater	S	Steering Wheel		

Motion analyzer data from a 21-year old male subject with no physical impairment were added to vehicle data to form Figure 2. Motion analyzer data, represented by triangles, were translated by co-locating the bridge of the nose with the design location for eyes. Left-side and head data only are shown in the side view. Control letter designations are deleted for clarity. In Figure 3, motion analyzer data from a 21-year old male driver candidate with achondroplastic dwarfism have been added to the vehicle graph in similar fashion.

DISCUSSION

Display of spatial relationships between driver range of motion and vehicle controls can be a valuable tool for prescription of adaptive driving equipment. Displays would also provide an objective basis for discussions with client, family, advocate, vehicle modifier, and other professionals.

A computerized approach is not necessary to display information. However, manually gathering and plotting data may greatly reduce cost effectiveness. An automated approach such as the one here is more flexible, faster, and less prone to error.

CONCLUSIONS

Graphic methods for evaluating spatial relationships between vehicle controls and client ranges of motion should be useful to evaluators of disabled driver candidates. Because of the enhanced visualization, it is expected that graphic approaches will lead to greater ability to specify control adaptations with fewer retrofits. The results will be lower cost, greater reliability, and less inconvenience to the driver.

ACKNOWLEDGEMENTS

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FIGURE 1.

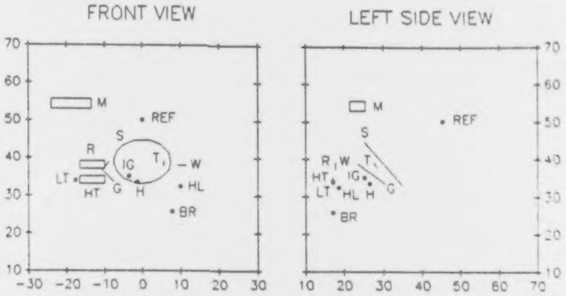


FIGURE 2.

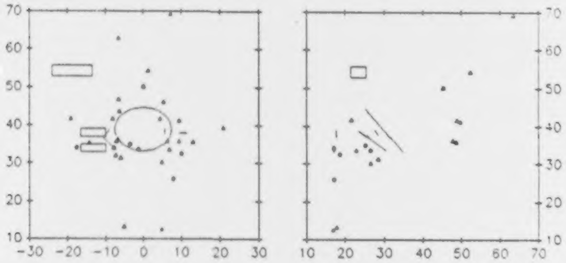
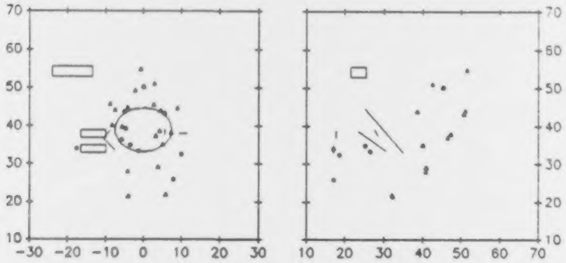


FIGURE 3.



“SPECIAL INTEREST GROUP”. 3

Augmentative & Alternative Communication Communications

ICAART 88 - MONTREAL

THE INTEGRATION OF MOBILITY AND COMMUNICATION INTO A TRAY DESIGN: A CASE STUDY

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INTRODUCTION

The challenge of integrating environmental control and mobility systems for persons with physical disabilities through the coordinating efforts of multi-disciplinary rehabilitation teams is well recognized (1). The Hugh MacMillan Medical Centre (HMMC), Toronto, is a childrens rehabilitation facility in which the staff has expertise in service delivery to the "hard to serve" population of children with physical disabilities. Within HMMC, the Augmentative Communication Service (ACS) provides assessment, prescription and training for clients whose speech is inadequate to meet their daily communication needs and for whom augmentative communication is required. ACS plays an important role in coordinating services to ensure functional integration of proper seating, communication devices and mobility. The design of trays and mounting systems plays an important role in the integration process relative to the client's ability to perform the skills required for the effective and efficient use of a communication aid. (Figure 1)

CLIENT DESCRIPTION

The equipment integration process is illustrated in the following case study: Louis is a 10 year old boy with severe disabilities resulting from Cerebral Palsy. He is athetoid, nonspeaking and dependent in all activities of daily living. His intellectual and receptive language skills are considered to be above average. He has well developed social skills for his age and is adept at personal decision making. Louis uses a range of augmentative communication displays on his lap tray and in portable folders. These displays contain Blissymbols, letters, words and phrases. He accesses these displays by indicating the wanted area with his eyes. His partner then confirms his eye gaze signals.

Louis' need for customized seating (a wheelchair insert) was provided by HMMC during his preschool years. At age 6, through the use of two head switches he was able to activate a wheelchair scanning device and thus became independently mobile.

Louis' transfer to a community school created a need to reevaluate his communication system. A new educational experience produced a change from one to one conversations to unfamiliar adult and peer communication partners who were frequently at a distance across a room. For this reason the ACS team investigated the possibility of a voice output system.

COMMUNICATION NEEDS AND SYSTEM PRESCRIPTION

The ideal aid for Louis would have high quality speech in English and Portugese (his family's native language). The portable speech output system would also need programming flexibility, i.e., preprogrammed letters, words and phrases, the ability to create novel messages at a reasonable speed and scanning options to accomodate any future changes in Louis' accessing of skills. For retrieval Louis needed a clear computer screen and the scanner (alternate keyboard) in proximity with a good, clear layout for easy eye tracking. Louis showed an interest in having the printed copy when creating a message for confirmation or for preparing messages in advance. The device had to be uncomplicated to operate for the user and facilitators. It should be easy to programme and make changes. Special attention had to be given also in the mounting of the device to include aesthetic appearance and to ensure that it not appear so technically sophisticated as to intimidate caregivers. The tray needed to come on and off in a simple way. While the Seating Department was concerned with the tray design, in the Department for Mobility a solution had to be found to integrate the mobility Scan Pac™ with the communication device so that the user would be able to alternate between driving and talking. The Epson Eval Pac™ (Figure 2) was identified as the device favoured by Louis and the one which met most of his needs.

INTERVENTION

In order to meet Louis' functional communication needs, his intervention program moved through progressive stages, each building upon the previous stage in a hierarchical fashion to finally provide him with maximum ability for the use of his new communication system. (Figure 1).

POSITIONING AND INTERFACING

Louis' seat is constructed to give him maximum support while not restricting him for function. With Louis' low tone in his trunk and his predominent flexor pattern, he is slightly tilted back and consequently needs a high anterior wedge (Figure 3, #1). He is further stabilized by a pelvic strap and a butterfly breast plate. Louis asked to have his flailing arm movements brought under control by securing his wrists to the tray with armcuffs (Figure 3, #2).

A neckrest supports his head (Figure 3, #3) and attached to it is his Multi Adjustable Mounting System for Switches. (Figure 3, #4) Louis operates his two Zygo Lever Switches (Figure 3, #4) by lateral head movements.

TRAY FEATURES

Louis' tray supports the Epson Scan Pac, the alternate keyboard (scanner and communication display) and his mobility and communication controller (Figure 3, #5 and #6). In order to conserve surface space, the Epson is supported by metal brackets and sunk into the lap tray (Figure 3, #7) at a 45 degree angle (Figure 3, #8). Special attention was given to secure fastening of the device. The Scan Pac™ alternate keyboard, with its scanning array, is mounted at an angle which allows maximum visual feedback from the LED on the scanner while facilitating Louis' physical stability in an upright position. It is important to keep Louis upright thus allowing him efficient switch access. The angle of the scanner is designed to minimize the risk of accidently activating the Epson's function keys (Figure 3, #8). There is easy access to the Epson so that Louis' facilitators (those who support him on a day to day basis) can remove it for programming or charging over night. The control box scanner (2) for mobility is small and protected by the outside rim of the tray (Figure 3, #9) and is placed to the side of the Epson in order to ensure Louis an unobstructed visual field. The elevation of the whole tray (Figure 3, #10) was dictated by the height of Louis' knees which are higher than his pelvic level because of anterior wedging of his insert. The tray is elevated at a 15 degree angle such that his elbows rest comfortably at a 90 degree angle. Lexan covers both the tray surface and the alternate keyboard to protect the scanner and communication display (Figure 3, #12) from moisture.

COMMUNICATION DISPLAY DESIGN

The programmed vocabulary for Scan Pac™ is arranged within three levels on a 1" x 2" matrix. Level one contains single words, level two alphabetical letters, and level three phrases. The display set levels are colour coded in mauve, yellow and blue. Additional locations provided the functions of "back space", "talk", "clear" and "print". The communication overlay placed over the LED array of the scanner and protected by the lexan cover (Figure 3, #5; #12). The remaining tray surface is made available to Louis for supplementary communication displays which provide him with rapidly accessed emergency and highly interactive vocabulary which he accesses by eye gaze in the event of equipment breakdown.

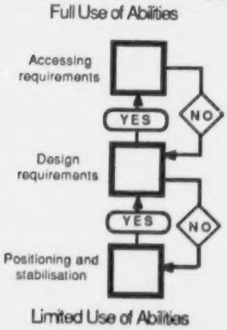
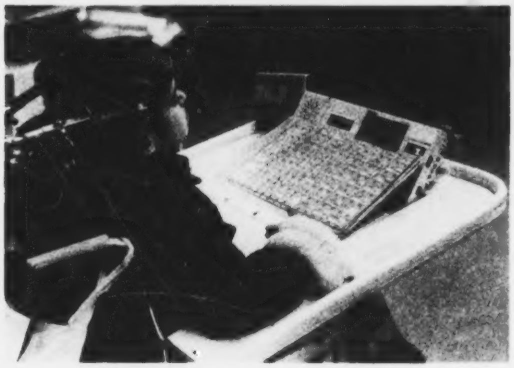


Figure 1

Figure 2



CONCLUSION

The combined skills of service delivery providers have met most of the identified communication and mobility requirements of the client in this study. Louis will be followed closely so that as technology changes, more of his needs can be addressed. For example, the anticipated development of the Scan Pac™ ability to speak different languages will provide him with the use of Portugese voice output in his home and community. The equipment he is now using provides access to the oral aspects of his communication needs and has the capacity to further support his developing independence and environmental control requirements.

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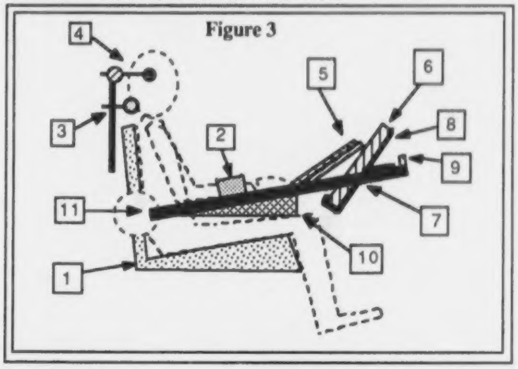


Figure 3

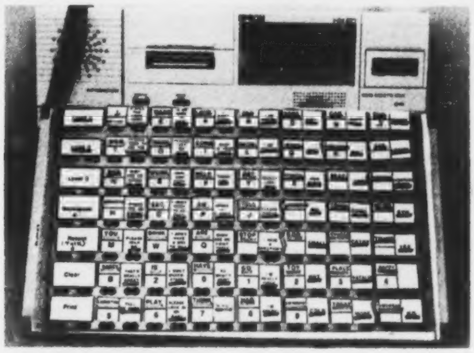


Figure 4

DU BLISS OU DE L'IMAGE, A L'ECRIT PAR SIMPLICOM

LINA LEMAY, orthopédagogue - LOUISE LEBLANC-LEFORT, orthophoniste
Centre François-Charon - Québec

DU BLISS OU DE L'IMAGE, A L'ECRIT PAR SIMPLICOM

Ce tableau spécial "du Bliss ou de l'image à l'écrit" favorise l'apprentissage global de la lecture et de l'écriture et permet aux utilisateurs d'avoir une communication plus spécifique avec leur interlocuteur.

Le vocabulaire (ou lexique) est regroupé selon l'ordre habituel proposé par le système Bliss par champ sémantique, grammatical et par couleur.

Les mots sont écrits sous les symboles ou les images en déclinaison, et la conjugaison des verbes est au présent sous le symbole à l'infinitif ainsi que le participe passé.

Ce tableau paradigmatique permet de garder un "stock" disponible (352 symboles ou images et 709 mots usuels), donc, 1091 mots de vocabulaire qui permettent de communiquer par symboles ou par écrit à l'aide de Simplicom.

Des règles de combinaison syntagmatique permettent de puiser dans ce "stock" pour former, au niveau du discours, des phrases.

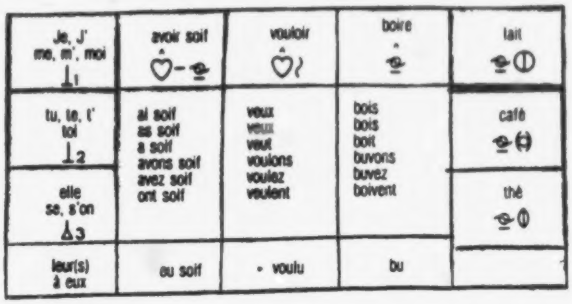
Le tableau de l'image à l'écrit est utilisé par les personnes qui éprouvent de la difficulté à communiquer à l'aide des symboles Bliss parce qu'ils sont trop abstraits pour eux.

Ce tableau, de l'image à l'écrit facilite l'apprentissage global des mots associés aux images et permet aussi d'avoir une communication plus spécifique. Il pourrait être utilisé avec des personnes en difficulté d'apprentissage à l'école, au niveau de la lecture et de l'écriture. Il pourrait aussi être utilisé comme mini dictionnaire, facile et rapide à consulter et donnerait un sens aux mots écrits lorsqu'ils font la lecture.

En orthophonie, ce tableau a été expérimenté avec certaines personnes aphasiques qui ont accepté de l'utiliser comme moyen de suppléance au langage parlé, à cause de l'écrit, alors qu'ils rejetaient tous les autres tableaux d'images qui ne répondaient jamais à leurs besoins.

La table de communication Simplicom est une aide technique qui permet aux personnes handicapées sévèrement de communiquer par écrit. Ces deux tableaux du Bliss ou de l'image à l'écrit sont programmés dans la table Simplicom et permet donc d'avoir une communication plus spécifique, en formulant des messages écrits, en élargissant ainsi le cercle de leurs interlocuteurs.

DU BLISS A L'ECRIT

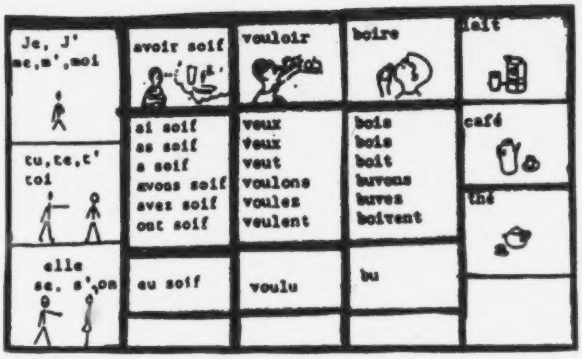


Je, J' me, m', moi	avoir soif	vouloir	boire	lait
tu, te, t' toi	ai soif as soif a soif avons soif avez soif ont soif	veux veux veut voulons voulez veulent	bois bois boit buvons buvez boivent	café
elle se, s'on				thé
leur(s) à eux	eu soif	• voulu	bu	

J'ai soif, je veux boire un café

Tu as eu soif et tu as bu un café avec moi

DE L'IMAGE A L'ECRIT


Je, J'
me,m',moi
avoir soif
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DU BLISS OU DE L'IMAGE, A L'ECRIT PAR SIMPLICOM

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TELECOMMUNICATIONS AND THE AUGMENTATIVE COMMUNICATION USER

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INTRODUCTION

The ability to speak to another person on the telephone is an activity of daily living we heavily rely upon in today's society. For the person who has difficulty moving about in our architecturally inaccessible communities, the telephone provides a valuable means of access to friends, family, necessary services and vocational opportunities. Widely available adapted phones (hands free phones and automatic dialers) have removed obstacles to using the phone for most physically challenged persons who are able to speak (1,2). However, access to telecommunications for the person with a physical disability whose speech is unintelligible has been given relatively little attention (3). This paper will discuss the use of computer mediated telecommunications by individuals with physical and associated speech impairments. Functional benefits and operational considerations will be reviewed and illustrated with a case example.

TOPIC DISCUSSION

Most voice output communication aids (VOCA's) are difficult for listeners in the immediate environment to understand. These aids are almost completely unintelligible over the phone. Typically persons who use augmentative systems without voice output as well as VOCA users must rely on one of two means of communicating over the phone: those who are able to vocalize establish a signal to indicate "yes" and "no" responses with familiar partners and limit their participation to one sided conversations which may result in frequent conversational breakdown; or the individual communicates via a speaking intermediary thereby sacrificing privacy and tolerating the speaker's interpretation of their message.

Consultants within the Augmentative Communication Service (ACS) of the Hugh MacMillan Medical Centre assess and address the communication needs of individuals whose speech is inadequate to meet their daily conversational needs. Consequently they are recognizing the importance of telecommunications, especially for nonspeaking persons who are competent computer users within independent living situations(4).

Functional Benefits

The needs potentially addressed by access to computer mediated telecommunication include:

- to interact with friends and family members at a distance who also have modems (ie. calling them up on the modem and holding a real time conversation);
- to access information resources (e.g., travel information, equipment information) and user groups (e.g., science fiction, chess);
- to access University databases, bulletins and library catalogues;
- to access community services (e.g., teleshopping, homebanking, transportation booking); and
- to perform computer related work at home and transmit it to the employer via modem, or to use a home based computer terminal to communicate with the employer's computer.

Operational Considerations

Operational skills which should be covered in training a user (who has established skills required to use a computer as a writing tool) to operate a modem and communications program include:

- dialing
- answering a call
- saving and printing text
- recognizing and responding to screen prompts
- sending a prepared file
- accessing a teleconferencing, bulletin or electronic mail service, if appropriate
- hanging up

When using the modem as you would use a phone, protocols for signalling the partner regarding a planned call using a modem as well as a signal to indicate the end of a communicative turn so that both parties do not try to "talk" at once should be established. As conversational partners cannot rely upon facial expression or tone of voice to assist in communicating the intent of their message, both parties must become skilled at using only the written medium to express this.

Equipment configuration

A wide range of modems and telecommunications packages are available. At ACS it was found that the following features are necessary for effective telecommunication:

- Both sides of the conversation should be displayed to both parties. (i.e., echo to screen)
- Text should be sent letter by letter as it is typed not only when a return is entered. It is very disconcerting for a listener to wait long periods of time for a response, not knowing whether a response is coming or the line has been cut.
- The program should have the facility to send prepared text files.
- It should be possible to send text to a printer, especially if accessing information services.
- A modem which allows you to hear "telephone sounds" (i.e., ringing, busy tone, a voice rather than a computer answering at the other end) is less frustrating to use.

Case Example

T.D. is a 27 year old civil servant with cerebral palsy, employed in a computer related job. He uses a wooden alphabet board (accessed through a head pointer), facial expression, eye gaze and limited vocalization for face to face communication. T.D. does not use a voice output aid. He feels that he can communicate faster by coconstructing his message with his communicative partner and is not satisfied with the intelligibility of available synthesized voices. For written communication he uses a portable MS-DOS computer both at home and at work, also directly accessed through his head pointer.

T.D. requested that ACS address his telecommunication needs. As T.D. expected to move into an independent living apartment he was concerned that his tightly budgeted attendant care time not be consumed by telephone conversations and booking transportation over the phone. He wished to use the modem to independently book Wheeltrans, the local accessible transit service. He had a number of close friends with modems, including a blind friend with whom it had not been possible to have a private conversation. He also desired access to computer bulletins including a chess user group, as he was an avid chess player.

At the time of assessment he used a speaker phone dialing with either his nose or headpointer. When communicating with familiar partners he indicated "yes" by vocalizing and "no" by remaining silent. This resulted in very one sided conversations whose success depended on the communiative partner's ability to predict what T.D. wished to talk about. When this mode failed conversations were intermediated by his attendant. T.D.'s utterances were typically novel in content and his vocabulary range so large that there was very frequent communication breakdown when he attempted to use a voice output aid to communicate over the phone.

T.D. was prescribed a program called Procomm and an internal Hayes-compatible modem. T.D. phoned his partners on the phone and vocalized to warn them that he would call them on the modem or to request that they call at their convenience. He chose to use an asterisk to signal the end of a turn. His partners used computers ranging from MacIntoshes, Tandy Model 100's to IBM compatible computers.

T.D. has successfully accessed a number of free electronic bulletin boards although his tight budget restricts him from more powerful teleconferencing systems. The local transportation service was approached to add the facility to read ASCII text to their TDD service. It was planned that T.D. would be one of the first "test-cases" to use this service.

T.D. reports that he finds conversations using the modem more equal as both parties are relying on the same mode of communication. He enjoys the privacy of conversations, the increased independence and the reduction of conversation breakdown. He reports that he misses the affective content of his partner's messages, usually expressed by tone of voice, especially with partners who are not skilled at expressing this feature through their written message.

CONCLUSION

Until the intelligibility of text to speech voice output drastically improves, computer mediated telecommunication may be a viable means of conversing with family and friends at a distance who have modems, for individuals who are non-speaking and physically disabled. The modem may also be used to access information resources, community services and vocational oppurtunities. User's feel that the increased independence, decreased communication breakdown and privacy gained outweigh the loss of the advantages afforded by the use of voice.

Having successfully applied the use of modems and telecommunications software with individuals like T.D. who's primary requirements are operational, clinicians at ACS are now exploring the use of these systems with multiply disabled computer users and users whose literacy is not well established. Issues which warrant further, more formal, exploration include:

- sending incoming text to a voice synthesizer to be spoken for individuals who have difficulty reading text and use other representational systems to write;
- transmitting graphic symbols(5); and
- developing text to speech voice output which is optimized for intelligibility over the phone.

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TARGETED APPLICATIONS FOR APHASIA REHABILITATION: COMPUTER-AIDED VISUAL COMMUNICATION IN APHASIA

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ABSTRACT

Researchers on the project entitled *Computer-Aided Visual Communication for Severely Impaired Aphasics* have developed software, specially designed for use by persons with severe chronic aphasia, which turns a standard Macintosh computer into a communicative assistive device. In clinical work with aphasic trainees on this system, the investigators have identified four specifically targeted applications for appropriately modified versions of their system. These four targeted applications are described below, and the scientific methods used to identify and explore these applications are characterized.

INTRODUCTION

Aphasia is loss of language in adulthood through brain injury. There are approximately 80,000 new cases of aphasia each year, mostly from stroke and vehicular accidents. Of these, 20,000 persons are left with severe, chronic language impairments. The most severely afflicted of these persons cannot read, write, speak or understand anything said to them. They are known as *globally aphasic* individuals. During the 70's, investigators in Boston reported qualified success in teaching globally aphasic persons to use an alternative communication system in the clinic, using pictures drawn on cards[1,2]. Since 1985, investigators at the VA's Rehabilitation R&D Center in Palo Alto, CA, have been implementing and extending the approach on an Apple Macintosh computer[3,4]. The initial application for the C-VIC system was as an alternative communication device for use by severe, chronic aphasic patients. In the course of clinical training, informal pilot studies, and scientifically controlled experimental investigations, we have revised that goal to include four potential applications for appropriately modified versions of the C-VIC software, all of which require that additional processing, control and display capabilities be built into the interface. The four applications are: *dialogue facilitator, aid for complex task execution, aid for intersystemic reorganization*, and *early therapeutic intervention*.

THE FOUR APPLICATIONS

1. *Dialogue facilitator*

As a dialogue facilitator, C-VIC systems are used to support more accurate and expressive communication between language-impaired individuals and their collocutors. In a variety of studies, researchers have already shown that aphasic trainees' *clinical performance* in C-VIC, both expressive and receptive, far exceeds their abilities in natural language[5,6]. This was reported from the research undertaken a decade ago as well, although that system never transferred successfully out of the clinic. In order to explore this latter issue, two C-VIC trainees have been loaned systems for use in their homes. Informal observation and reports by family suggest that the current version of the interface does play a role in fulfilling certain communicative needs. The system is reported to be used by the patient and those around him, in particular, when conversations of some importance that take place, in which all want maximum possible verification that they are understanding each other correctly. It appears not to be used, on the other hand, to support the easy, informal communicative exchanges between people which are so characteristic of language, and which was one of our initial goals.

2. *Aid for complex task execution*

One C-VIC trainee with a system at home has been participating in studies to determine whether a modification of the C-VIC interface can help him reach functional performance in cooking. Recipe preparation is a cognitively complex task for which even able-bodied individuals require performance aids, such as cookbooks or videotapes of recipe preparation. In a preliminary uncontrolled phase of the investigation, recipes from packaged mixes were simplified and recast into a series of C-VIC instructions, which were presented in proper serial order to our trainee. With no prior instruction, and with no feedback on the accuracy of his individual steps, the subject — who was reportedly never skilled in the kitchen — successfully prepared four different recipes on four successive occasions. Each time, the results were declared edible, with gusto. The fifth time, the subject was given the recipe virtually identical with one previously successfully prepared, but with instructions retranslated from the simplified C-VIC form into English. This time, the dish was destroyed and the results were declared inedible. This informal pilot study suggests our new application for C-VIC, and scientifically controlled studies on aspects of the subject's performance are currently underway.

3. *Aid for intersystemic reorganization*

Intersystemic reorganization is a rehabilitation technique often used to improve the communicative performance of aphasic individuals. It relies on using a relatively unimpaired modality to provide support for improved performance in a relatively impaired modality. For example, a patient with difficulty remembering the main components of a propositional sentence may have a robust gestural system, which could be trained to help him out. In fact, the Russian aphasiologist Luria reported cases over forty years ago in which visually based systems were used to improve the spontaneity and grammaticality of aphasic patients' speech[7]. Such a result leads us to believe that an appropriate adaptation of the C-VIC system could be widely useful to the rehabilitation of properly selected patients. It is an idea whose application and evaluation will require the generation of targeted methodologies, assessment tools, and monitoring tools, however. We are just beginning to address these issues, in collaboration with colleagues at the VA Medical Center in Martinez, CA.

4. *Early therapeutic intervention*

Adaptations of the C-VIC approach may be beneficial to aphasic individuals in the early months of recovery following brain injury. This is the time of most rapid recovery, as the period of acute physiological disruption passes, and the patient begins to work on regaining functional performance. It is a time during which the administration of traditional speech therapy can make a positive difference[8]. Supplementing such traditional therapies with C-VIC activities may improve outcomes yet further. For one thing, C-VIC work can be initiated at the patient's instance, rather than being dictated by the speech pathologist's schedule, and can be available for drill around the clock. The computer can handle highly repetitive tasks accurately, without becoming bored or irritable, and can keep careful real-time documentation. In addition, use of a computer is generally observed to be highly motivating to patients. One comparison of the efficacy of computers versus clinicians in administering traditional therapy to aphasic individuals found computers slow but equally efficacious[9]. A proposal by colleagues in Boston to investigate this C-VIC application has recently been approved for three years of support, and initial work is now underway there.

DISCUSSION

In pursuing work on these applications, we use clinical observations, informal pilot studies, and scientifically controlled experimental study designs. The first yields lists of possible valuable applications for C-VIC development, as well as suggestions for modifications of training protocols. The second produces detailed descriptive accounts of subject performance on particular tasks, or of performance following a particular training protocol. Where findings here continue to show promise, we seek to explain the reasons for patients' success through rigorously designed, scientifically controlled studies, using single-subject experimental designs[10]. The identification of the four potentially promising C-VIC applications comes out of work structured in this way.

The development of new rehabilitative techniques, particularly where new technology is involved, is a complex and time-consuming process. One must address several issues: identifying appropriate applications; developing the technology; producing proper assessment, training and evaluation techniques; generating materials to disseminate the approach widely; and establishing mechanisms for the continuing support and upgrading of the applications. This paper shows results of applying our methodology to the first of these major tasks, i.e., identifying promising applications.

ACKNOWLEDGEMENTS

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A MICROCOMPUTER-BASED COMPREHENSIVE ASSESSMENT/TEACHING/TRAINING CLINIC FOR THE COMMUNICATIVELY DISABLED

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ABSTRACT

The combination of a wide variety of computing hardware, software, input possibilities and output display formats, seen against a background of widely differing user needs and capabilities, can create a morass of therapeutic and education choices which the average speech or physical therapist is ill-equipped to handle.

Over the past few years we have endeavoured, in our Cybernetics and Human Assessment laboratory to offer the widest possible choices - both hardware and software, so that the best match between user needs and technology could be effected. Various inputs, outputs and supportive software tools have been either constructed or adapted for general usage.

BACKGROUND

During the last 5 years, our group has developed considerable exposure to, and facility with, APPLE II(E), IBM COMPATIBLE and BBC-MICRO/MASTER hardware and software used for aumentative and alternative communication, education, training, employment and recreation.

In addition we have endeavoured to widen the choice of input modalities, and output presentations so that whatever capabilities and needs which were appropriate to a particular client could to the greatest extent possible be provided. Various input and output modalities are listed in tables 1 and 2 respectively.

MATERIALS AND METHODS

However, in attempting to match inputs or output to the particular hardware interface on the one hand, and the driver/service routines on the other, we have identified many pitfalls and blocks, some correctable by "soldering or software" changes but others remaining frustratingly unamenable to solution. The reasons for these failures are various, but chief contributing factors have been the unavailability of detailed technical information about hardware and software "hooks" to enable entry into the inner workings of machines.

Where the architecture of machines is sufficiently open, we have often been able to build custom hardware to effect the particular combination of input/output, hardware interface and servicing software. Examples of this include replacement of up to four input selection switches by a joystick which when not used in the communication-task, is employed for electric wheelchair control; and speech output, suitably formatted, as an alternative to the VDU screen or printed text.

If only the logic flow and high-level language listings of programmes used by disabled clients could be available under strict licence from the originators, much better customisation could be possible. As things are, we are very often forced to make serious compromises in order to achieve at least a half-satisfactory result.

The BBC machines, which are the National Standard for General and Special Education in the United Kingdom, have a much more open and accessible architecture/philosophy than any others that we have encountered, and are fast becoming the de facto norm in special education in Southern Africa. The wide variety of AAC/educational software makes this sytem even more useful.

In addition, to cater for those who cannot access conventional keyboards and who are in electrically-driven mobility devices, we have developed an Infra-red (I-R) RS232C serial link. Using the same joystick or switch which they have developed a familiarity for environmental or wheelchair control, these clients are now able to "plug in" to an I-R input port and address the microprocessor/computer directly from a mobility device without needing any assistance. They can therefore come and go as they wish.

In parallel, working closely with Interface: Total communication for the disabled, a community organisation, we have established a Toy Library called 'TOYSWITCH'. Parents and therapists can borrow suitable battery-operated toys, and appropriately chosen control switches to attach to them enabling young pre-school disabled children to respond to stimuli and learn to initiate interactions with their environment.

We feel that this cause-effect pretraining is essential for the non-verbal and/or non-dextrous child to learn certain basic concepts, in order to prepare the child for hands-on computer usage later. This is particularly important for severely disabled children whose life/play experiential opportunities are severely curtailed. Using first toys, and then later, simplistic manipulation of objects, shapes, and colours on a computer screen by single or double switch actions, they learn such abstract concepts as relative size, space, distance, up-down, left-right, hidden objects etc.

CONCLUSION

By having a wide variety of choices with reasonable interchangeability of inputs, outputs and programmes, we feel we can offer clients: disabled, parents and therapists an optimal match to their needs and abilities.

There is a good argument for training institutions such as ourselves not to get locked in to any one computer/system and thereby become unable to choose the best from various sources to adapt these devices to ideally match personal needs.

ACKNOWLEDGEMENTS

Without the help and cooperation of the members of INTERFACE, Cape Town Region and the technical support of the Biomedical Electronic and Mechanical Laboratories, most of this programme would have been impossible.

TABLE 1 : INPUTS

- Single switch
- Double switch (sip-puff)
- Multiple switch (serial or chordic)
- Joystick
- Mouse
- Headpointer
- Speech/sound
- Touch-screen/tablet
- Bar-code reader (BCR)
- Optional Character Reader (OCR)

TABLE 2 : OUTPUTS

- VDU Screen
- LCD/LED arrays
- Speech/sound
- Printed-text/graphics
- Vibrotactile
- Braille reader
- Modem/autodialler
- Environmental controller

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A MORSE CODE COMMUNICATION DEVICE FOR A DEAF-BLIND INDIVIDUAL

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ABSTRACT

A communication system utilizing currently available inexpensive technology for a deaf-blind individual was developed. As a result of contracting encephalitis the client sustained total loss of vision and hearing accompanied by temporary quadriplegia and neuropathy in his hands. The client's speech remained unafected, but he was left without a method to receive information auditorally or visually. This paper will discuss the process of determining an aided receptive communication system and the capabilities and limitations of the system developed.

INTRODUCTION

The use of Morse code as a means of sending signals to achieve access to electronic communication devices or personal computers is well documented (1), (2). With these methods, the disabled user sends the code, usually by a series of switch closures and the microprocessor translates the code for output to a display or speech synthesizer. In this case Morse code was utilized not as a means of sending information, but or receiving information for a client who lost his vision and hearing.

CLIENT BACKGROUND

The client, a thirty-four year old male construction worker contracted encephalitis and subsequently had a complete loss of his hearing and vision. He was quadriplegic with confinement to a wheelchair for six months after onset. He regained his ability to ambulate, but continues to experience moderate neuropathy in his hands affecting his ability to receive tactile information. Cognitive or language functions were not affected and his speech remained intact.

He received intensive physical, occupational and speech therapy services while a patient in a hospital based rehabilitation unit. Although his speech was not affected, his communication partners had no method to send or transmit information. Several tactile methods were attempted with limited success. For example, an alphabet board was devised in which his communication partners traced his finger tips over the surface of carved letters. Due to a limited range of motion in his upper extremities and reduced feedback through his finger tips, this method proved to be cumbersome and unreliable.

The most successful unaided method of communication proved to be through tracing letters on the palm of his hand. As each letter was traced, the client would say the letter and his partner would confirm the accuracy of the response with a predetermined yes-no by tapping on his arm (one tap for yes, two for no). The primary problem presented with this method was the fact that each communication partner had a slightly different way of tracing letters. Due to the reduced tactile feedback this resulted in having to "relearn" for each person spelling on his hand.

EVALUATION

An evaluation determined that the client had sufficient tactile feedback through his hands to accurately discriminate between hard and soft taps. His Speech-Language Pathologist provided three weeks of training to teach him the Morse code alphabet by tapping on the top of his hand with one finger. After this initial training period, his rate of receiving information was slightly faster with Morse code that through traditional spelling.

DEVICE DESCRIPTION AND APPLICATION

At this point, a device manufactured by Heathkit (figure 1) called the UltraPro (3) was acquired (Model HD-8999). This is essentially a portable battery operated device used by Ham Radio operators to send Morse code through a conventional QWERTY keyboard. As the userinputs to the keyboard, the device emits a series of audible tones in the form of Morse code. The "dits" are relatively shorter in duration than the "dahs". The speed of sending the tones is variable from a keyboard adjustment. Output is through a small speaker connected to the device. The device was modified by adding a one watt speaker/amplifier (Radio Shack, Model 32-2031) connected to the UltraPro through the headphone jack. The speaker on the amplifier was exposed so the client could rest his finger tips directly on the vibrating part of the speaker. The factory provided speaker was removed.

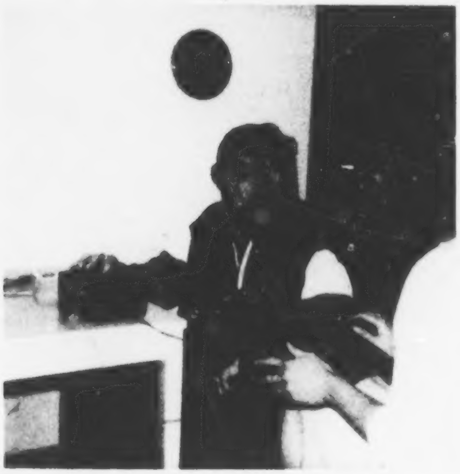

Figure 1. HeathKit UltraPro

As the communication partners typed on the keyboard, the client received the vibratory signals in the form of Morse code and encoded them into letters and words. Initially, this was difficult, since the vibratory sensation provided by the device was considerably different than the hard and soft taps that were used in learning Morse code. With practice, the client was able to make the transition and encode the vibrations with accuracy equal to tapping.

In order to facilitate and accelerate the communicatin process, the client learned to "guess" words being spelled based on the context provided by previous letters in the word and words in the sentence. When a partially spelled word was correctly guessed, the communication partner would go on to the next word or sentence, thus increasing the rate of communication by approximately fifty percent.

CONCLUSIONS

This receptive communication device was both inexpensive (approximately $200.00 in materials) and relatively easy to use for this particular client. Other tactile based communication devices were ruled out due to the client's difficulty in receiving tactile information. This device with its added amplifier provided an output signal strong enough for the client to decode using residual tactile feedback.

As he regained his ambulation, portability became an issue since it could no longer rest on a wheelchair laptray. This was compounded by the fact that he was simultaneously using a cane and learning techniques for mobility. This was partially resolved by packaging the device in a brief case.

Over a three month period of time after receiving the device, actual use in various communication environments varied depending on the situation. His wife, for example found it more expedient to continue to spell words in his hand since she found it inconvenient to "setup" the device every time she needed to say something. Friends and other professionals found the device more functional than hand spelling or tapping. The device provided a consistent signal whereas hand spelling was often irregular and inconsistent. The fact that his communication partners required no special skills other than typing on a QWERTY keyboard was an advantage that the other methods did't offer.

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THE USE OF SOUND-TO-SPEECH TRANSLATION AND EXPANSION WITH CHILDREN AND ADULTS WHO ARE MENTALLY RETARDED

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INTRODUCTION

For some persons with severe disabilities, communication is something they cannot take for granted because they are unable to communicate by typical means. Modern advances in electronic technology have delivered many of these individuals out of a silent world. For others with the most severe handicaps, however, the technology may exist, but its applications have yet to be appropriately designed.

There are upwards of two million people in the United States whose physical and/or mental impairments are so severe that they are unable to communicate or interact with the environment in an effective manner. Of these two million, 300,000 individuals are severely or profoundly mentally retarded, that is, with IQ's below 35 and accompanying impairment in adaptive behavior (Grossman, 1984). There is 100 per cent speech and language dysfunction in persons with IQ's less than 20, and a 90 per cent speech and language handicap in persons with IQ's between 21-50 (Gould, 1977). Often for those who are severely retarded, language consists only of unintelligible utterances or nonvocal efforts to communicate. Additionally, this population is generally beset with severe physical limitations that contribute to inadequate communication skills, unsatisfactory physical abilities, and overall reduced quality of life. All these circumstances typically result in extreme frustration, passivity, and helplessness (Floor & Rosen, 1975). If a means could be provided by which such persons could communicate intelligibly and exercise their choices, significant increases in their independence and their ability to participate more fully in the mainstream of society would result.

Continuing on a track of research that is exploring applications of technology that will allow persons with severe mental retardation and physical handicaps to control their environment and communicate with the world around them (Brown, Cavalier, & Tipton, 1986), the Bioengineering Program at the National Headquarters of the ARC has developed a computer-based system that accepts keyboard, single-switch, and voice input and delivers environmental control and digitized speech output that is mediated through a reconfigurable dynamic visual matrix.

SYSTEM FEATURES

The main features of the system are as follows:

Voice Input

The system incorporates the Votan 2000 voice recognition circuit board and software routines. Each user can store voice templates for sets of 64 items, consisting of sounds or word phrases of up to 2 seconds per item in duration. Multiple users can simultaneously store templates for their item sets and access them. The templates for each item can be entered into the system in 2 to 3 passes each.

Sound-to-Speech Translation and Expansion

The system incorporates an algorithm that translates any designated sound input that is recognized, whether intelligible or not, into a specified speech output. For example, if a user's vocalization for water approximates "wuh" and s/he speaks only in single-syllable vocalizations, the system can quickly output "Could I have a drink of water, please." The output is digitized speech generated by the Votan 2000 circuit board. Any single speech output can be up to 5 seconds in duration, permitting single words or complete sentences to be output.

The system can communicate in an "immediate" mode in which each single input is immediately output in its translated form. The system can also communicate in a "delay" mode in which the system holds each successive input in a queue and then outputs the complete spoken translation upon command. The "delay" mode provides the user re-combinative and generative language capabilities. The system provides translation-editing functions under voice, switch, or keyboard control. The user can adjust the volume of the spoken output from a normal conversational level to a private whisper under voice, switch, or keyboard control.

BEST COPY AVAILABLE

Environmental Control

The system incorporates X-10 technology permitting user control of up to 256 electrical devices in the environment. Any voice (or other) input can be linked to the activation and de-activation of any electrical device. A single voice input can also be linked to any combination of spoken outputs and device activations. The system incorporates a BCD videocassette controller interface to permit voice control over the fast forward-play-rewind functions of a videocassette recorder. The system also provides the user telephone dialing and answering capabilities via the Votan 2000.

Visual Mediator

The system incorporates a dynamic visual mediator between the user and the available communication and environmental control options. The mediator consists of one or more screen pages containing text referents for the available spoken outputs and device activations. The referents can be lexical representations of the corresponding voice input of the user, the corresponding system output, or any other character-string the user or teacher chooses. Each screen page is a matrix configurable to individual user needs in terms of the number and size of the rows and columns that define the matrix cells.

The location of any referents on any page is specified by the user or teacher. The user or teacher can also specify the colors of the letters and the background of each referent to facilitate categorical clustering. The referents for translation-editing are available to the user in a drop-down window on any page. The system reserves the last line of each page to display the spoken expressions that are constructed by the user in the "delay" mode. The system allows the user or teacher to define a window that contains referents for a subset of spoken outputs and device activations that can be opened on any page.

The system provides options on the following modes for a user to make selections on the pages: (a) direct selection (through voice), (b) coded direct selection (by screen location), (c) continuous linear scanning, (d) row-column scanning, and (d) directed scanning. The user or teacher specifies the speed of scanning. The user has the option of directing the communication output to a printer in addition to or in place of the speech synthesizer.

DISCUSSION

The system has undergone three rounds of tests in 1987. As a result of these tests system refinements have been incorporated in terms of speed of output, ease of training the voice templates, and a more friendly visual interface. The system provides a versatile means by which a severely handicapped user can interact with the surrounding human and physical environment. Users who are severely mentally retarded and physically involved who typically possess only the rudiments of language can use the system to begin to map out the cause-and-effect relationships in the environment and begin to learn the practical referential meaning of single-syllable utterances. From this foundation, the system can also be used to teach the fundamentals of combining two items to increase communication versatility. Because of the system's programmability the system can be re-configured to be appropriate for a developing student as his/her needs change. A person with sophisticated language skills can use the re-combinative abilities of the system to generate a wide variety of individualized communications from the stored templates that comprise his/her vocabulary.

ACKNOWLEDGEMENTS

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BLISSYMBOLICS AND TECHNOLOGY

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INTRODUCTION

The system of Blissymbolics has the capability to serve as the graphic representational system for several components within an individual's augmentative communication system. Blissymbols can be applied to communication boards for face-to-face interaction, voice output communication aids, software for written output, software for learning to read and telephone communication (under development).

The system features of Blissymbolics, along with the variety of ways in which it can be utilized and the manner in which the system can be complemented with embellishments, pictures and letters allow the developing nonspeaking individual to learn and use one graphic representational system prior to the mastery of traditional orthography. In addition, the consistent use of Blissymbolics within several communication applications allows the individual to develop strategies that will contribute to his/her competency as an adult communicator.

In this presentation, the system of Blissymbolics is considered a tool within an individual's total communication system. As such, it is an "extension of the tool user", providing him/her with a "medium that the user works with" (1). Through applying this tool, the individual can refine and expand his/her communication capabilities over time, with a variety of technological systems, which in themselves can be considered as tools.

BLISSYMBOLICS

Blissymbolics is a pictographic and ideographic symbol system that was originally developed by C.K. Bliss as an international communication system (2). Blissymbols are composed of meaning-based units, some of which depict the outline shape of the concept represented (pictographic) and others which utilize shapes that relate to an idea associated with a referent (ideographic) (3). Whether the Blissymbol consists of one unit or several, it is intended that the root meaning of the symbol be explained in a way that relates to the cognitive level of the learner.

Blissymbolics offer two major advantages to the user in approaching literacy and communication competency: The user need not know how to read, spell or analyze words into their phonetic components; he/she can select and transmit the meaning elements of the message rather than the traditional orthographic representation of the message's words. Secondly, the time and physical movements required to produce a message are kept to a minimum. The user can produce messages which are concise and efficient by attending directly to the meaning intended and including only essential information. The refinement (or expansion) of the message is then left to the receiver.

The relatively simple line shapes of Blissymbols allow them to be easily written by hand and displayed or printed with computers. Blissymbols provide a valuable bridge to traditional orthography (TO). Students' experiences in reading and writing Blissymbols can be related directly to all school language learning.

Through licensing agreements with C.K. Bliss in 1975 and 1982, Blissymbolics Communication International has legal aughority to provide a worldwide standard for all published Blissymbols. New Blissymbols are being added annually to the vocabulary.

COMMUNICATION BOARDS

The vocabulary items (representing words, sentences and phrases) and the manner in which primary and supplementary displays are arranged, constructed and accessed, depend upon the needs of the user (5,6,7). Samples of these displays and photographs of primary boards integrated with voice output communication aids (8) will be displayed in the poster session. Examples will be included with vocabulary items that demonstrate pictures and traditional orthography being used to enhance the system capabilities of Blissymbolics.

VOICE OUTPUT

Three features of Blissymbolics make it worthy of consideration as the graphic system for use with voice output.

Strategies

As Blissymbols have been used through the years by nonspeaking persons, certain symbols within the system have come to be used in special ways. Examples of strategy symbols include "opposite meaning", "similar in meaning", "similar in sound" and "combine symbol".

Indicators

Within the Blissymbolics system, indicators are used with other symbols to denote verb tense, mood, voice, plurality, and part of speech.

Sentence Forms

In Blissymbolics there are patterns available for statements, questions and commands in both positive and negative form. Students can learn these patterns within their interpersonal communication and apply the rules to voice output.

The memory capabilities now available allow many of the above strategies and rules to be utilized for voice output accessed by Blissymbols. The capabilities of Blisstalk (9) and Blissbook (10) with regard to the application of linguistic rules, will be demonstrated at the poster session. Examples of Blissymbol overlays for the Epson Speechpac (11) and VOIS 135 (12) will also be displayed, along with descriptions of several software programs for the Apple computer that have been available for several years (13, 14, 15, 16).

BLISSYMBOLICS AND TECHNOLOGY

SEMANTIC COMPACTION

The potential for Blissymbols to serve as multi-meaning icons along with other pictorial representations is being examined through a whole language approach in which the individual uses Blissymbols on his/her communication board, on his/her Touch Talker or Light Talker (17) and as his/her means of producing written output (18). A suggested overlay and set of Blissymbols for utilizing word strategies will be displayed. The iconic technique of Minspeak™ shares with Blissymbolics a direct reference to meaning and offers a powerful component to a communication system for the person that enjoys using the strategies of Blissymbolics in innovative ways (19).

TELEPHONE COMMUNICATION

Over the past two years, work has been undertaken by the IDON Corporation (Ottawa), and a team from: McGill University, MacKay Centre School, Shriners Hospital, Montreal and the Blissymbolics Communication Institute toward the development of a Blissymbol telephone capability (20). The progress of Phase 1 and Phase 2 will be indicated.

SUMMARY

The importance to the developing individual of applying one graphic representational system for several components within his/her communication system and literacy program deserves the attention of augmentative communication specialists. This poster session demonstrates the capabilities of Blissymbolics applied to technology for undertaking this role.

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BLISSCOM: TELECOMMUNICATION FOR NON VOCAL PHYSICALLY HANDICAPPED INDIVIDUALS

Terry Gandell, Dr. Cynthia Weston, & Kathleen Moffatt

Introduction

Microcomputer technology provides a link to the world for special populations. This presentation is focused on one unique application: the development and evaluation of a telephone-like system for non vocal severely physically handicapped individuals whose primary means of communication is blissymbolics - a meaning based graphic system. Effects of providing a telephone to this population has implications in the areas of communication, integration, future development, and applications.

Objectives:

1. To demonstrate that, using the Blisscom prototype software, the subjects could successfully telecommunicate with others.
2. To identify problems in the software to assist in creating a marketable product that provides consistent independent use for the subjects.

General Results:

Both the quantitative and qualitative data strongly suggest that the system was a viable means of communication, and the users enjoyed and benefitted from its use. The two main sources of quantitative measurement (number and length of communications) increased over the course of the project.

A general analysis of group performance reveals that the problems encountered were the result of apparent flaws within the software itself.

General Discussion:

The subjects could successfully telecommunicate with others. The field trial indicated that Blissymbol telecommunication is extremely feasible. While the problems were significant, we firmly believe that they can be solved. Further, until more features are added, and the system is made more rugged, Blisscom will be unecessarily limited in its potential application. While the current software functions adequately enough to permit telecommunication and prove the feasibility of the system, there remains a considerable amount of improvement and refinement.

To further investigate the potential application for Blisscom, a follow up project is recommended in two phases. The first phase would entail the develoment of French and English software packages with appropriate supporting materials to incorporate both official languages. This initial phase would also address revisions such as expanding the current Blissymbol dictionary, adding features and functionality to more closely approximate the Comprehensive Checklist, and porting the software to three other commonly used microcomputers to allow for a wider scope of communicators. The second phase, implementation, would demonstrate the usefulness of this telecommunication system for the physically handicapped non vocal population. The use of a variety of implementation sites and the selection of pretested participants from various settings would provide a broader picture of the general suitability of the system. It is expected that the new communication capabilities provided by the system would have an effect on daily living skills, community involvement, and opportunities for education. The system might offer an ideal method of distance education for small populations of severely physically handicapped young people who lack specialized community services. Social integration and a general improvement in the quality of life , even at this time, can be predicted.

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A MULTI PURPOSE TRAY FOR YOUNG CHILDREN

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INTRODUCTION

Access to a variety of toys provides children with sensory, motoric, cognitive, communicative, and social experiences. The convergence of biological, psychological and social growth with learning principles is essential for the promotion of sound human development. Significant elements found to enrichof learning are participation in meaningful activities, a clearly defined and effective participant role, and interactive relationships which encourage independence in the developing child. (1)

The development of language, speech and communication occurs simultaneously when meaning and information is transferred between partners during conversations. Children, whose speech attempts cannot meet their communication needs, often enhance their linguistic attempts by nonlinguistic modes such as eye gaze, facial expression and gestures. Formal communication systems such as pictures, Blissymbolics, etc. may also be used to augment communication. (2). Analogous with the use of alternative communication modes for children with special needs is an instructional approach which addresses the associated cognitive requirements of successful interaction.

THE IDENTIFIED POPULATION

Young children with special needs require the opportunity to experience sensory, motor, cognitive, communicative and social activities. Too often they are well seated in their insert or adaptive positioning device and are placed so that the world flows on around them providing little opportunity to develop biologically, socially and psychologically. Children's learning and growth also requires that they participate effectively within meaningful activities and within interactive relationships with others. (1). Their development of language, speech and communication occurs when meaningful information is transferred between partners during conversations. Children with special needs and limited communication skills may either use non-linguistic modes such as eye gaze, facial expression and gestures or formal communications systems (pictures, Blissymbols) (2) to enhance their communicative attempts.

The multipurpose tray described here is one clinic's attempt to meet many of the young child's needs described above. Designed to be used by the client when seated in an insert, the tray provides a variety of mounting adaptations, surfaces and features. Toys, communication accessories, fine motor stimuli and sensory media can be attached quickly and easily to open the opportunities for shared meaningful communication/play with other people.

The adaptive tray discussed in this paper is appropriate for young children who, due to physical disability, have the following needs:

- to develop the sensory, motor, cognitive, communicative, and social skills necessary to permit mastery over one's self and one's environment
- to engage in the meaningful activity of environmental exploration (play), and
- to have a common ground for social interaction and communication with others.

The prescription of an adaptive tray can support cognitive and communicative development by providing the child with the opportunity to learn about:

- objects/toys and their functions
- object permanancy
- cause-effect relationships
- the skills required for choice making and
- sharing common social opportunities to stimulate interactions with familiar partners and strangers alike, thus enriching opportunities for learning

CONSIDERATIONS

Tray assessment and design, due to the intricate relationships of arm and hand function with posture, should be considered during the seating assessment, however, the details are decided upon once seating is complete. Bergan and Colangelo (3) discuss tray assessment and measurement in addition to postural modifications. Carlson (4) and Goossens' and Crain (5) have elaborated on creative play and communication modifications which enrich the range of options available to tray prescribers. These authors have illustrated a variety of play/tray surfaces with strategically placed tracks or slits to secure small toys; E-Tran activity frames to suspend toys or communication displays; wells or recessed containers to hold sensory media or toys; and A-Frame/inclined surfaces to support books or communiation displays. As well they have noted the relative benefits of clear/see-through plastic versus wood/non-transparent trays. Reference to these works will stimulate the creative thinking of tray designers and prescribers as they encompass the body of knowledge available.

With growing technical awareness and therapeutic intervention for people of varying ability, tray designers and prescribers must also consider the mounting and integration of switches, electronic toys, manual graphic displays, voice output communication aids, and powered mobility controls. Currently, mounting systems are being developed to provide client safety and device versatility.

CASE ILLUSTRATION

Jonathan is a three year old boy with Cerebral Palsy (quadraplegia). He is seated in a modular insert, placed in a stroller for transportation. Jonathan lives at home and attends a segregated morning preschool program.

Jonathan needs to stimulate the development of the skills and abilities of childhood (e.g., concept development, communcation, motor...); to engage in meaningful activities (to play); and to generalize his skills and learning across environments. Table 1 lists the features of the adaptive tray matched to the constraints and goals for Jonathon .

TRAY DESCRIPTION

The lexan tray is 20" wide by 21" long. It consists of two 1/4" layers bolted together with a stepped cut-out to support a translucent container and variety of panels (one plain, others with tracks, velcro, dycem, indoor/outdoor carpeting, etc. to permit a variety of mounting strategies). A pop-apart E-Tran made from PVC tubing and dowel and an adjustable A-Frame (small incline surface) are attached to the top edge of the tray. The tray mounts onto the insert armrests with lexan sliders.

CONCLUSION

This tray incorporates novel integration of many features developed and described by Carlson (4), A & C Goossens' & Crain (5) and ACS staff. The identified tray features could easily be adapted for others - i.e., older, lower functioning clients and individuals requiring the integration of highly individualized equipment and communication displays. The goal of the paper is to stimulate the thought processes of tray designers and prescribers to promote objective analysis of the client's needs and the desired tray features. Ideas regarding potential alternatives and insights have also been provided.

The authors wish to thank all colleagues whose sharing has led to the development of Jonathan's tray;and Judy Dziuba (typing).

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Table 1: Tray features matched to constraints and goals of the client.

CONSTRAINTS	TRAY FEATURES
• Jonathan exhibits fluctuating muscle tone; his arm movements are performed within the limited ranges of full extension or flexion. All movement is slow and hands are predominantly fisted.	• The small tray supports his forearms in a relaxed, neutral position. All toys and accessories stay within his optimal range.
• He is small for his age, has limited reach range and little muscle and fat to pad him.	• The available work surface is small to avoid dwarfing him, and devoid of sharp edges and rough surfaces.
• Seizures are controlled by medication but he is at risk.	• The tray is fast and easy to remove; with no sharp edges.
GOALS	
• **Sensory.** Jonathan is oversensitive to different textures and is at the stage of sensory exploration (touch, manipulation and mouthing). He needs to practice open-handed contact with objects.	• The tray permits exposure to a variety of textured stimuli and sensory media (water, play dough, sensory toys) within optimal visual/auditory and functional range.
• **Motor.** Jonathan has difficulty holding his head up. He requires stimulating objects to reach and grasp/manipulate.	• The A-Frame and removable E-Tran permit presentation of objects/pictures at eye level for natural gaze. The tray permits a variety of arm positions and facilitates self control of movement in midline. Securing of objects in containers/on tracks promotes hand contact with the attachments.
• **Cognitive.** Jonathan is developing knowledge of objects and their functions and the concepts of permanency, cause/effect and attention to objects and social contexts.	• Toys are suspended from the E-Tran or attached to tracks cut in the tray to prevent falling or movement out of range. Versatile mountings permit attachment of a variety of items.
• **Communication.** Jonathan uses eye gaze, facial expression and minimal gestures to communicate. Training in picture/ symbol use is provided. Eye gaze must be readable by his communication partner.	• E-Tran presentation of objects and pictures facilitates eye contact with partners. Projections don't obscure vision or obstruct hand function.
• **Social.** Jonathan relies upon his environment and non-vocal communication to attract and sustain communication. Opportunities for interaction must provide common ground for holding attention.	• The tray and attachments must be interesting and varied. The tray is light, easily portable, and hopefully important enough to be remembered by caregivers.

COMMUNICATION PAR L'IMAGE

Lina Lemay, orthopédagogue   Louise Lefort-Leblanc, orthophoniste

Communication par l'image est une méthode d'apprentissage entièrement illustrée, destinée pour une clientèle adolescente et adulte. Il s'agit d'un matériel d'appoint créé pour faciliter l'enseignement des connaissances de base nécessaires au bon déroulement des activités de la vie quotidienne, l'entraînement ou le réentraînement à la communication orale et/ou non orale et pour la réadaptation de certaines fonctions cognitives et perceptives.

Ce matériel didactique comprend 1050 mots de vocabulaire, 70 images synthèses auxquelles sont reliées 70 séquences composées de quatre images chacune. A cet ensemble se rajoute un tableau d'images pouvant aussi être utilisé comme mode de communication.

La conception de ce matériel didactique a été réalisée par une équipe multidisciplinaire du Centre François-Charon (Claire Dumont, ergothérapeute, Louise Lefort-Leblanc, orthophoniste, Lina Lemay, orthopédagogue), pour répondre à un besoin pressant de posséder des illustrations s'adressant aux adultes et non pas d'utiliser, avec des adultes, des illustrations où les thèmes abordés, les valeurs véhiculées, le vocabulaire et la représentation imagée conviennent aux enfants.

Le matériel est donc approprié pour des personnes en rééducation: accidentées cérébro-vasculaires et traumatisées crânio-cérébrales ayant des atteintes des fonctions cérébrales supérieures. Il est aussi approprié pour des personnes en apprentissage ayant une déficience physique et/ou intellectuelle et/ou sensorielle, avec un niveau élémentaire de connaissances ou une faible scolarisation. De plus, il peut être utilisé avec des personnes immigrantes, analphabètes et pour des adolescents(es) présentant des problèmes d'apprentissage.

Pour l'utilisateur, il a l'avantage d'illustrer des séquences de la vie courante de l'adulte afin d'augmenter sa motivation à l'apprentissage et faciliter le transfert des connaissances acquises à la vie quotidienne. Il est conçu de façon à fournir des modèles qui favorisent l'intégration des personnes vivant avec une déficience. Pour l'intervenant, il regroupe un nombre impressionnant d'illustrations couvrant l'ensemble des situations de la vie adulte. Différents types d'intervenants pourront l'utiliser pour le traitement et l'apprentissage et l'adapter pour en faire un outil d'évaluation.

Pour faire un système de communication ordonné, cohérent, permettant de faire divers apprentissages et de varier les utilisations, nous avons appliqué une méthodologie rigoureuse tant pour le choix des mots de vocabulaire que pour le type de graphisme et le mode de représentation des concepts illustrés.

Les 1,050 mots de vocabulaire ont été choisis après une étude des listes de vocabulaire de base de la langue française. Plus de 16,000 mots ont ainsi été répertoriés, compilés, regroupés et enfin triés selon des critères précis pour enfin parvenir au classement de 1,050 mots. Ces mots ont été ensuite regroupés en 11 catégories soient: 392 représentations concrètes, 230 actions, 70 personnes, 40 groupes, 32 sentiments, 111 qualificatifs, 18 opérations intellectuelles, 50 mots généraux, 27 représentations du temps, 10 voeux et souhaits, 70 mots outils.

Pour créer les images séquences et les images synthèses, nous nous sommes inspirés des catégories que nous avons identifiées dans notre choix de vocabulaire, en se guidant sur les actions de la vie de tous les jours, l'organisation de notre style de vie nord-américain et en respectant les objectifs d'apprentissage, de normalisation et d'intégration que nous nous étions fixés.

Elle sont concues de manière à utiliser le vocabulaire de base dans une activité concrète et près du vécu de la personne en vue de favoriser l'apprentissage et l'utilisation du vocabulaire dans la vie courante.

Aucune inscription n'est faite au recto des illustrations, mais il y a une inscription bilingue (française et anglaise) au verso indiquant de quel mot de vocabulaire, de quelle séquence ou de quelle synthèse il s'agit.

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L'EVALUATION INTERDISCIPLINAIRE INFORMATISEE
(COMPUTERIZED INTERDISCIPLINARY EVALUATION)

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SOMMAIRE

Ce papier a pour but de présenter un modèle d'évaluation interdisciplinaire informatisée mise sur pied par les thérapeutes d'un programme de suppléance à la communication orale, pour répondre aux besoins d'enfants handicapés moteurs sévères et non-oraux.

ABSTRACT

This paper presents a computerized interdisciplinary evaluation tool conceived by the therapists of an alternative and augmentative communication program in order to meet the needs of non-verbal and severelly handicapped children. It regroups items evaluated in three major disciplines; that is, in occupational therapy, speech therapy and psychology. These are principally perceptual, cognitive and comprehensive skills. Although we find this tool very useful for evaluation purposes, we are aware that more testing is needed before we become able to determine its utility and validity.

Ce logiciel d'évaluation fut développé par les thérapeutes du programme de suppléance à la communication orale (S.A.C.O.) de l'Hôpital Marie Enfant, c'est-à-dire l'ergothérapeute, l'orthophoniste et le psychologue et ce dans le but d'enrayer certaines difficultés ou certaines lacunes rencontrées lors des évaluations traditionnelles. Toutefois, il est important de préciser que ce logiciel n'est pas encore disponible puisque l'élaboration du protocole de correction ainsi que l'étape de validation ne sont pas encore complétées.

C'est donc à la suite d'un long cheminement et d'une remise en question constante que les membres de ce programme arrivèrent à la conclusion suivante: malgré les raffinements et les adaptations apportées aux moyens d'évaluation déjà existants dans chacune des disciplines, nous rencontrons encore beaucoup d'insatisfactions. D'abord, ces évaluations n'étaient pas accessibles à une partie de notre clientèle présentant des handicaps moteurs sévères, ce qui évidemment, nous empêchait de recommander un outil de communication optimal. Deuxièmement, le désir d'évaluer tous les éléments pertinents aux objectifs de ce programme et ce dans le plus court délai possible, nous évitant dans un premier temps de retester à maintes reprises certains items et dans un deuxième, de fournir le plus rapidement possible un outil de communication fonctionnel.

Ainsi, pour des raisons de disponibilité de matériel, nous options pour la conception d'un logiciel adapté pour l'ordinateur Apple II+, IIe, ou II GS. Nous rendions alors ce logiciel accessible à tout genre d'interrupteur simple distribué commercialement, sans l'utilisation de la carte "Adaptive Firmware". Le choix de réponse se fait par un système de balayage et la vitesse du curseur est réglable.

En ce qui a trait au contenu à évaluer dans chacune des disciplines, en voici une brève description.

Initialement, l'ergothérapeute effectue une évaluation motrice dans le but de sélectionner le meilleur accès à l'ordinateur et vérifie la compréhension du système de balayage. Suite à cette préévaluation, l'évaluation interdisciplinaire est passée.

En ergothérapie, l'évaluation se situe principalement à deux (2) niveaux:
A. La perception visuelle
B. Le schéma corporel

Dans le module "Perception visuelle" on évalue plusieurs élémements dont:
1. les formes
2. les couleurs
3. les grandeurs
4. le balayage
5. la superposition d'image
6. les relations spatiales

Il est à noter que chaque élément est subdivisé en sous-catégories, permettant ainsi différents niveaux de difficultés. De plus, l'évaluation permet non seulement de savoir si le concept est intégré, mais également si le bénéficiaire parvient à faire une association du concept à évaluer.

Dans le module "Schéma corporel" les éléments évalués sont:
1. la discrimination du sexe
2. les parties et fonctions du corps
3. les articulations du corps
4. l'habillement

En psychologie, l'évaluation cognitive comprend trois (3) épreuves piagétiennes, soit:
- la permanence de l'objet
- la classification
- la sériation

Ces trois (3) épreuves nous permettent de situer les enfants ou les jeunes évalués à l'un de ces trois (3) stades:

sensori-moteur	(~0 à 2 ans)
préopératoire	(~2 à 7 ans)
opératoire concret	(~7 à 15 ans)

Finalement, en orthophonie, on retrouve cinq (5) tests différents qui évaluent principalement la compréhension du bénéficiaire. Ceux-ci sont les suivants:
1. Carrow
2. Discrimination auditive
3. Rebus
4. Syllabation
5. Wh?

CONCLUSION

L'évaluation interdisciplinaire informatisée semble être un outil intéressant pour répondre aux besoins de notre clientèle. Toutefois, il n'en demeure pas moins qu'avec une utilisation plus grande, nous serons en mesure d'évaluer son utilité et sa validité.

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LE JEU ADAPTE, UN PREMIER PAS VERS L'AUTONOMIE

CAUVIN, Claire Ergothérapeute, PROJET JEUX ADAPTES
LEFEBVRE, Luce Ergothérapeute, PROJET JEUX ADAPTES

ENGLISH RESUME

This poster session will present the adaptive toys project at H.M.E., a pediatric rehabilitation center serving Montreal and Western Quebec. The object of this project is to set-up a toy library for physically handicaped children. We will discuss the role of technology in adaptive toys for other complex utilization. Our goal is to make available toys that will encourage the development of severely handicaped children and give them pleasure.

INTRODUCTION

L'hôpital Marie Enfant dispense des services d'adaptation et de réadaptation à des enfants et adolescents présentant une déficience physique de type moteur.

Dans le cadre d'un mandat supra-régional, Marie Enfant dessert une clientèle résidant sur le territoire de l'ouest du Québec. De plus, il offre des services à des enfants et adolescents handicapés physiques fréquentant des écoles de la Commission Scolaire des Ecoles Catholiques de Montréal et de Chomedey à Laval.

Un projet de mise sur pied d'une ludothèque est actuellement en cours;il a pour but de mettre à la disposition de la clientèle, une diversité de jeux et jouets considérant les incapacités motrices et les limitations fonctionnelles qui en découlent.

OBJECTIFS DE LA SEANCE D'AFFICHAGE

- Faire connaître les applications cliniques de la technologie utilisée pour rendre des jeux et jouets accessibles à des enfants et adolescents présentant des incapacités fonctionnelles sévères.
- Susciter un échange visant à développer de nouvelles applications de la technologie dans ce domaine, afin d'ouvrir de nouvelles avenues pour notre clientèle.
- Démontrer que l'utilisation d'une diversité de jeux et jouets accessibles permet de stimuler les différentes étapes d'apprentissage chez l'enfant handicapé physique et favorise l'actualisation de son potentiel physique, psychologique, cognitif et social.

Clientèle visée

Le projet s'adresse à une clientèle âgée de 6 à 18 ans, présentant des déficiences motrices telles la paralysie cérébrale, maladie neuromusculaire et musculo-squelettique. L'atteinte motrice de ces enfants limite leur accès au jeu.

Une certaine partie de notre clientèle d'enfants présente des déficits sensoriels et intellectuels pouvant bénéficier de l'utilisation des jouets accessibles.

DISCUSSION

1. Polyvalence au mode d'accès:

Pour répondre aux besoins d'une clientèle présentant des handicaps variés, le jeu-jouet peut accepter plusieurs modes d'accès:
- système à balayage;
- manette de contrôle;
- différents types d'interrupteurs simples.

Ce fonctionnement rend accessible à chaque enfant fréquentant la ludothèque, un plus grand nombre de jeux-jouets électroniques et maintient son intérêt.

2. Lien existant entre le jouet adapté et les aides techniques:

L'expérimentation en cours démontre que l'utilisation de jouets accessibles dans le processus de réadaptation permet à l'enfant de développer des habiletés pour l'apprentissage d'aides techniques plus sophistiqués tels que fauteuil roulant motorisé et contrôle de l'environnement. Toutes ces aides techniques sont indispensables pour permettre à l'enfant handicapé d'acquérir une autonomie optimale dès son jeune âge, favorisant son intégration sociale et sa participation active aux différents rôles sociaux.

3. Une diversité de jeux-jouets:

Ceci est nécessaire pour supporter l'acquisition des pré-requis à ces apprentissages en offrant à l'enfant, des défis à sa portée.

CONCLUSION

La technologie ouvre un accès au jeu, à plusieurs enfants sévèrement handicapés.

Nous souhaitons que dans un futur rapproché, un plus grand nombre de jouets soient accessibles commercialement, et que l'on puisse cerner les lacunes existantes dans plusieurs aspects du jeu (le jeu symbolique et le jeu de société, etc.), afin que l'enfant handicapé parvienne à un développement harmonieux.

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A CLINICAL APPROACH TO AN AUGMENTATIVE AND ALTERNATIVE COMMUNICATION PROGRAM

PROGRAMME DE SUPPLEANCE A LA COMMUNICATION ORALE - APPROCHE CLINIQUE

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ABSTRACT

This presentation aims to demonstrate the approach and philosophy of an alternative and augmentative communication program in a pediatric rehabilitation center. Children are usually severely physically handicaped and the goal of our program is to provide technical support as well as consultations to the therapists who have clients that are non-oral.

Our expertise centers principally in developping evaluation tools as well as in selecting the appropriate communication device available for the french population. We promote a good follow-up of the communication system in order to modify or adapt the latter if need be, as the child grows.

SOMMAIRE

Cette présentation par affichage illustrera l'orientation actuelle et la spécialisation du programme multidisciplinaire de suppléance à la communication orale développée à l'Hôpital Marie Enfant de Montréal.

Le centre de réadaptation Marie Enfant, offre ses services aux jeunes handicapés physiques de l'ouest du Québec âgés de 0 à 21 ans. Cette clientèle se distingue par le caractère de complexité du handicap, de la permanence de la déficience et par un potentiel de récupération. Dans le cadre d'une structure de fonctionnement par programmes multidisciplinaires, le programme SACO est un programme de soutien technique qui offre des services de consultation et d'expertise à la clientèle présentant des problèmes de communication orale.

La création du programme il y a 5 ans, répondait à un besoin spécifique du milieu de réadaptation; les ressources étaient méconnues, il était difficile d'identifier les besoins et on ignorait à quel âge commencer les interventions. A ce moment, l'équipe prenait en charge l'évaluation, la recherche d'aides techniques, le choix du mode de communication, l'entraînement, la sensibilisation du milieu et le suivi. L'équipe a eu à développer ses outils d'évaluation, à analyser les systèmes de communication disponible (Bliss, Pic, etc.) ainsi qu'à suivre le développement de la technologie des aides à la communication.

Cinq ans plus tard, nos fonctions se sont orientées sur des tâches plus spécifiques. La formation et la sensibilisation des intervenants du milieu de réadaptation, nous permet actuellement d'agir comme consultants, de raffiner nos évaluations pour intervenir dans les cas plus complexes et de privilégier l'intervention précoce, dans le but de développer la communication chez le jeune enfant d'âge préscolaire qui reçoit peu de services dans le système actuel.

Notre expertise s'est donc centrée autour de **l'évaluation.** Tout d'abord, nous procédons à l'évaluation des **prérequis à la communication:** attention, processus cognitifs, habiletés de communication. Nous considérons ces prérequis essentiels à l'amorce d'une approche à la communication. Conséquemment, des programmes de stimulation sont donc offerts aux parents et intervenants directs pour favoriser le développement de ces prérequis. Dès la maîtrise des prérequis, nous poursuivons par l'identification des potentiels. Les habiletés de l'équipe formée d'un responsable médical, d'un ergothérapeute, d'une orthophoniste, d'un psychologue et d'un coordonnateur clinique, nous permettent d'identifier les potentiels moteurs, perceptuels, cognitifs et de communication. Le cumul de ces données ainsi que les formations provenant du milieu familial, scolaire et de réadaptation, oriente le choix d'un système de communication efficace, fonctionnel et personnalisé. Le mode d'accès à ce système de communication est également notre préoccupation; nous disposons d'un éventail d'aides techniques commmerciaux, et de prototypes, ce qui nous met à la fine pointe de la technologie (!!!) en communication, spécialement pour la clientèle francophone. Nous utilisons pour l'entraînement, des jouets adaptés avec des interfaces et différents logiciels adaptés pour répondre à nos besoins et ceux de notre clientèle.

Nous devons également tenter de prévoir les besoins futurs du jeune, de sa maturation et de l'évolution de ses potentiels; notre choix s'oriente donc vers des modes de communication qui pourront évoluer avec lui ou qui pourront progresser avec lui, selon les étapes de son développement. Cette planification permet au jeune d'éviter d'être limité dans sa communication. Nous favorisons par exemple, (séquentiellement):

- l'approche avec l'objet jumelé au système oui-non
- la photo de l'objet
- la représentation graphique de l'objet
- la représentation symbolique d'objets, de besoins et de concepts
- la représentation phonétique du système linguistique (le "ECRIRE", l'alphabet...)

Le passage de l'un à l'autre de ces systèmes, se fait au moment où le jeune possède le potentiel cognitif et le besoin d'étendre son potentiel de communication, favorisant un enchaînement harmonieux, plus nature, sans la perte d'énergie reliée à l'apprentissage de différents modes de communication. Nous favorisons les modes de communication qui seront les mieux intégrés dans les milieux de vie du jeune et encourageons le développement constant des habiletés à communiquer.

Le programme de Suppléance à la Communication Orale tel que précédemment décrit, tente de remédier au cumul de déficits et de déficiences occasionnés par un handicap moteur sévère et un manque d'expérience associé à une pauvre communication. Ceci souligne l'importante d'un dépistage, d'une orientation précoce, et d'un suivi de l'évolution de la communication dans le but de réussir l'intégration scolaire et sociale du jeune non-verbal.

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FUNCTION AND CONTENT WORDS IN A PREDICTIVE SYSTEM

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Introduction

A communication system for the physically handicapped which significantly reduces inputs during the process of text entry has been developed at Dundee (1). This software, which is called PAL (Predictive Adaptive Lexicon), utilises language redundancy by offering the user word predictions from a dictionary. PAL adapts automatically to the users vocabulary by capturing words as they are used and storing them in the dictionary so that they may thereafter be offered as predictions. PAL can offer the user a character saving of over 50% during text composition.

The PAL dictionary contains statistical information for each word concerning its frequency and recency of use. This information gives an indication of the probability of a word which is used when compiling each prediction list. The true probability of occurrence of a particular word, however, is not based on its past frequency of occurrence alone, but also on other factors such as the syntactic class of the previous word(s), the context of use, and position in the sentence. In certain situations PAL will therefore offer predictions which are not appropriate. This can be particularly obvious in the 'default prediction list' which is offered before any characters of a word are entered. A typical default prediction list might contain: 'the', 'of', 'and', 'to', 'a'. If the previous word had been 'the' none of these predictions would ever be likely.

Syntax in Prediction

One step towards remedying this would be to include syntactical information in the dictionary. When compiling a prediction list the word frequencies used could be modified according to the probability of occurrence of the particular syntactic pai-

This approach has been investigated and found to produce what looked like much more accurate predictions, although in numerical tests there was only a slight improvement in key saving figures(2). There are a number of difficulties, however, in producing a practical system. It is necessary to use a fixed dictionary built prior to use so that syntactical information may be included. If adaption is used, the dictionary may degrade over time because it may be difficult to infer accurately the syntactic class of an unknown word. Also Some words should be assigned to more than one syntactic class according to their context, of use so a more complex syntax tagging must be used to resolve ambiguities.

Function Words and Content Words

Words in English language can be divided into two groups, the function words, also known as form, grammatical or accessory words, and the content or lexical words. The function words are usually made up from the articles, prepositions, copulas, conjunctions, pronouns, determiners, and auxiliary verbs (3,4,5). We thought that there may be advantages in dealing with these two groups in somewhat different ways within a predictive system. A list of function words was compiled from the top 1000 words in the Brown corpus (6). Some words which are often classed as adverbs were also added as these seemed more appropriate in the function word list, for example: 'also', 'not' and 'then'. Of the first 100 rank words 88 were in our function word list, the next 900 supplied a further 75. A transition matrix has been produced indicating whether a particular function word pair could possibly occur; this uses one bit per entry. This matrix has been added to the PAL system and is used to modify the word frequencies used when compiling a prediction list in a similar manner to the syntax transition matrix. In this way the function word matrix is used to reject unlikely combinations and hence to make room in the prediction lists for more useful words.

This treatment of the function words particularly affects the default prediction list. After a non-function word has been entered, the default prediction list of highest frequency words similar to that shown previously is displayed. When a function word has been entered the transition matrix is used to reject improbable combinations. For example, after the word 'the' has been entered, the prediction list now contains: 'other', 'first', 'most', 'many', 'much'. After 'and' the list contains: 'of', 'which', 'the', 'to', 'a'. After 'he' the list contains: 'and', 'is', 'was', 'had', 'would'.

Although the frequency of an invalid function word is reduced, the user can still access this word, but more characters will have to be entered before it is seen in a prediction list. For example, if the user selects 'which' (one keystroke after 'and' as above) he will have to enter 'wh' before 'which' is seen again in a prediction list. Hence no matter how unlikely a combination is it will still be allowed.

Conclusion

Incorporating a function word transition matrix into PAL provides more appropriate predictions without requiring any changes in the dictionary system. Function words are still treated as normal words and their statistical data still reflects actual usage. Also function words may still be added to and deleted from the dictionary thus retaining the full dynamic characteristics of the dictionary. This has produced a valuable performance enhancement in the predictive system at a small overhead. The predictor is more pleasing to use as particularly obvious incorrect predictions no longer occur. This may also encourage the use of function words in text and may be particularly appropriate for Broca's Dysphasics who have a particular weakness in this area.

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PROTOTYPES OF FAST TEXT COMPOSITION SYSTEMS;

Design criteria and evaluation problems.

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Introduction

The use of statistical/linguistic approaches to enhance the speed of text composition is now well recognized as a valid and practical tool. Several papers (1) have been published in the last years. There are also several working systems; some of them are even commercially available. Until now, not much evaluation is reported. At least, no comparative field evaluation results are known.
This paper will deal with two applications of linguistic knowledge in text composition systems. These systems are based on protypes developed at Tufts University, Boston (2) and University of Dundee, Dundee (3).
The actual design of a working system involves large number of decisions in the field of ergonomics. Especially, the procedures for error correction are of paramount importance (4). Next paragraph describes the systems and gives a list of ergonomic criteria to be incorporated.
Than a presentation of results as they are available at this moment will be given. The results will only deal with the technical/functional aspects. There is no user evaluation done yet: not in the laboratory, nor in the field.
A discussion of the problems of comparative experiments will be given. Finally, future activities are discussed.

Prototypes

The first system involves a combination of the WRITE system from Boston (5) and the PAL system developed in Dundee. The WRITE system is basically an pointing board which has frequent occurring character strings in the cells. Word composition is done by consecutive indication of cells. A global average is that 2,6 cells have to be indicated for a word. The PAL system is a word completion predictive system with an adaptive lexicon. The PAL system gives upto 40 to 60 percent of keystroke savings. This means that a global average for one word, including space is about 2.7 keystrokes.
The WRITE system had to be adapted to the Dutch situation. A design is made with 300 cells of which 20 cells are needed for numbers, controls and punctuation marks.
The system is put on a "Keyport 300" touch sensitive panel and connected to a "MS"-DOS personal computer which PAL is running.
The combination of WRITE and PAL might further decrease the number of keystrokes. It is not known yet to what extent a further decrease of keystrokes per word can be expected. Experiments are executed to solve this question. It is expected that an input of a string of characters from the Keyport into the PAL will diminish ambiguity and might result in an immediate and proper selection. An important question is whether or not the WRITE-PAL combination will proof to be a convenient solution in a field situation.
The screen-keyboard (Keyport) interaction in this system seems comparable with the normal PAL system. A difference is, however, in the decision making at the moment that the normal situation, it is highly probable that in the list of predictions in case of the WRITE-PAL, the correct option is present. The effect of this phenomenon can only be tested in a practical test situation.
The second system, in a prototype phase available, is the decoding system, based on a 12-key keyboard with direct access capabilities. This system is based on ideas and preliminary research done at Tufts University (6). The letters of the alphabet are grouped on 12 keys like a telephone keypad. The asterisk key and the number sign key have special functions. In normal use in a deaf telephone situation a two fold keystroke has to be given, i.e.: the first stroke to indicate the group of characters and the second stroke to select one of the three characters on that particular key. By means of usage of language statistics, a computer can select or "predict" automatically the correct characters, thus the second keystroke can be omitted. With presently available software this selection is 89 percent correct. In 11 percent of the cases, the user has to correct the character as predicted by the computer.
The way it goes on the computer is that during typing the text appears on the screen; in a small window, at the end of the text the three possible characters are given. The computer predicted character is in the first position. The least probable character in the last position. Just by hitting a correction key (the asterisk key) the next character is put in first position. Operating another character key will accept the first character of the window as correct text.
From the viewpoint of information theory, a decision on a 12-keypad is probably as difficult as on a normal single letter-on-a-key keyboard. The decision on the 12-key keypad might have an extra component as is making the relation between character and key itself.

The detailed structure of error correction, and the psycho-motoric component in the keying procedure will determine the ease of operation.

Evaluation problems and experimental set-up

The envisaged systems, in a prototype phase existing, require new learning and new adaptation to their pecularities. Furthermore, there are different kind of abilities required for these systems. Thus, although one of the systems can be better from a theoretical viewpoint, the specific cognitive and motoric abilities of a (handicapped) person might result in a better performance with another system.

In a comparative test, one has to assure that the, eventually impaired, cognitive and motor abilities are not a limiting factor in neither of the systems. For a objective comparison, equal training time, equally difficulty of text is required. Different samples of text are needed during training and for each experimental session. Based on these considerations, it was decided to find text samples for training and experiments which are similar with respect to a number of parameters.

These parameters were: 1) Average length of sentences; 2) Average length of words; 3) Type Token ratio; 4) Coherency within the text sample; 5) Identical topics.

The length of the text samples was chosen to be thousand words. Two different topics were chosen, i.e.: one from a novel of Thomas Mann which is rather descriptive in situations and one topic is sport reports in the weekly extra edition of a national daily newspaper. For each of these topics there are 10 different samples of text chosen.

The coherency of text and the Type Token ratio are rather crucial in comparing predicting systems. This is especially important in the case that the systems are adaptive and based on frequency data or/and include linguistic rules on a syntax level.

From the above, it might be clear that written text generation is chosen in the experiments. A communication situation which involves direct interaction requires another set-up. Such a situation is much more difficult to simulate in an experiment. Generation of free text as a response on simple questions might come rather close. The questions has to evoke simple, rather short descriptive answers.

Thus, three communication situations are available for experiments: - Text copying from samples of a novel; - Text copying from samples of a sports report; - Free text generation in response of questions.

We have planned to execute comparative evaluations with the following systems: a) Normal keyboard; b) 12-Key system; c) PAL; d) WRITE-PAL; e) WRITE. The results will be reported later on.

Conclusions and discussion

It is seen that new techniques now available due to the evolution of computer technology give a higher speed of communication. The savings of keystrokes is, until now, the only comparative figure which is published. The value of this variable (i.e.: between 40 and 60% for the various systems) is not giving a dependable insight in the actual usability of these systems. Feedback situations, and the relation to user abilities might result in an unpredictable outcome in field situations.

The discussion on the set of text samples for experimental use leads to the conclusion that a list of criteria has to be defined which are international acceptable. Comparisons for different languages will than give more insight between each of the languages.

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Validation and Testing Program of the Expert System ADIS: Assistive Device Interface Selector

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ABSTRACT:

The expert system ADIS (Assistive Device Interface Selector) has been designed to match the abilities of orthopedically disabled individuals to control interfaces for communication devices. The testing plan specifies three phases for validating the accuracy of the ADIS output. Within each phase of testing, the prototype undergoes iterations of revision and debugging. Preliminary testing (Phase I) of the prototype has been performed in the Berkeley Expert Systems Technology Laboratory by the knowledge engineer. In the on-going second phase, the evaluation is based on field testing though comparison with human experts and data compiled from clinical records. The last phase will require actual use of the delivery system by novices in training and other target users. Initial validation through clinical testing at the Children's Hospital at Stanford revealed new expert knowledge, as well as directions for improvement to the existing expert system. Current findings indicate the system lacks in-depth problem solving abilities that will need to be corrected for the delivery system. Unexpectedly, findings also indicate the potential of ADIS as a software tutorial tool for assessment training. The methods, observations and conclusions obtained through the first two phases of field testing of ADIS will be discussed.

INTRODUCTION:

Disabled individuals use control devices to attain independent mobility, communication or control over their environment. The standard design of a communication system involves evaluating the client's capabilities and configuring off-the-shelf components that meet these requirements to maximize the client's functional flexibility. Many practitioners are conveniently located near clients, but only a few possess the experience of a skilled clinician to evaluate and identify appropriate controls. This poses travel costs and inconveniences to both expert practitioners and clients.

As a solution, the ADIS expert system described previously [1] has been developed. ADIS is a software program that provides non-expert therapists with a systematic procedure with which to evaluate disabled clients for control. The user is asked a series of questions by the system regarding the client's abilities, or is given instructions and procedures on how to perform a test in order to acquire the necessary quantitative information. The data collected is used to make decisions along an assessment path based on the systematic approach used by Barker and Cook [2]. Ultimately, the ADIS system recommends a candidate interface for a given controllable anatomic site based on the data. Developed on an IBM AT computer, the ADIS software runs on the TI Explorer, IBM PC's or other compatible computers. A description of the test phases and their results follows.

METHODS:

Phase I: Preliminary Testing

Validation of the ADIS expert system is required to ensure it performs the tasks it was originally designed to do. Before presenting the system to target users, preliminary testing, debugging and software verification was completed by the knowledge engineer to ensure the integrity of the knowledge base and the reachability of all possible solutions. Static testing involved checking individual rules and facts in the knowledge base for both consistency, accuracy and completeness. Rules which are not consistent have decision parts (consequents) that conflict when two mutually exclusive decisions are simultaneously satisfied. Additionally, accuracy tests check for incorrect inferences, and completeness tests check for unused decision paths and rules, and unreachable goals.

Because the knowledge engineer is not an expert in the field, in-depth validation through actual use by both the expert and target users is required. It is necessary for the expert to test the system against actual clinical test cases and those unexpected problems encountered during an evaluation. The expert's role in testing is vital because the expert knows how he/she would solve problems and how he/she would like the system to perform. Preliminary testing in ADIS was completed in the fall of 1987.

Phase II A: Clinical-Site Testing

The ADIS prototype was installed at the Children's Hospital at Stanford for run-time consultation. The expert Peggy Barker performed the first step of field testing by creating a small set of hypothetical cases that were designed to encompass a large set of solutions. These cases combined a diverse, although likely, range of client abilities. Any discrepancies between the system's response and the expert's judgment were recorded as necessary revisions to the system, and immediately reported to the knowledge engineer for modifications.

Phase II B : Comparative Case Testing

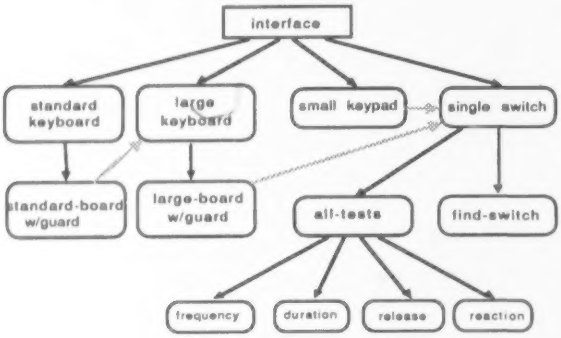
The on-going second phase of validation involves reviewing and compiling data taken from files of clients evaluated in the past. The data collected includes the speed (activations/minute), error scores, types of errors and movement characteristics. These clients were those who had no previously prescribed devices or training with one. The values from the records are then placed into ADIS as if an evaluation is being performed. Again, any contradictions or inconsistencies between the expert's predicted responses and the system response are recorded as problems. The expert is asked to keep track of the problems encountered, including any inaccuracies, inconsistencies, out-of-sequence problems or deficiencies. All trial runs are stored on floppy disks as well as the hardcopies of all the play back responses.

RESULTS:

Phase I: Preliminary Testing

The initial review of the prototype uncovered additional decision paths in the hierarchy of test interfaces and switches that need to be modeled. This resulted in reorganization of the rules and existing frame architecture, specifically the goals and subgoals for two entries. The updated frame representation is given in figure 1. Solid lines indicate inheritance to a subframe, whereas the shaded lines indicate a possible alternate path of frame instantiation. This provided possible alternate paths of frame instantiation. Several graphics screens that provide pictorial help were updated and appended, as well as explanations to the user.

Figure 1: Frame Representation



Phase IIA: Field Testing

The expert found the ADIS system to adequately imitate her approach methodically, in-breadth (rather than in-depth). By using hypothetical test cases, the expert became aware of more options and alternative paths not previously considered. The system has prompted her to think in a forward reasoning manner, generating more decision paths or alternatives in the expert's mind. Also, the process of evaluating knowledge and inferences of the ADIS system has caused the expert to be more aware of her own reasoning methods and uncertainty. ADIS has forced her to re-evaluate and question her methods and formalize her knowledge.

Since many clients have previous experience with keyboards, the need for modified speed tests that include typing tests and a program to evaluate the number and type of errors was identified.

Phase IIB:Comparative Testing

Results from this portion of testing are inconclusive at this point in the study. In some cases, recommended interfaces do not match the prescribed device because previous records were either incomplete and certain tests were not performed. Also, the system, as expected, was found to be weak in evaluating clients with inconsistent motor control (i.e. athetoid CP) for single switch testing, as different rankings are required depending on the nature of the client's disability and control.

DISCUSSION:

Codifying knowledge for the ADIS expert systems is challenging because the knowledge base of interface selection is dynamic, continually being modified and refined as clinicians exchange ideas and optimize their approach to client assessment. The new knowledge and specific rules that need to be added to the system must be identified, and the old rules rewritten or eliminated due to conflict or redundancy. As more knowledge is added to the system, trade-offs must be made between performance and development time. As more rules are entered, the time required to incorporate new knowledge as well as the time for the system to find a solution increases.

It was assumed that the recommendations made in past clinical evaluations were based on the same reasoning approach and principles encoded in ADIS. Past clinical records were well documented in terms of client abilities and tests performed. However, many of the tests that were incorporated and implemented into ADIS were skipped in the expert evaluation of a client due to obvious problems that led to "quick-jump" decision making. The system was unable to handle unexpected information, such as that visible by the expert, or supplied by family or medical records. Although ADIS was designed to handle incomplete and uncertain information, the system was often unable to reach a conclusion because too many values were unknown or incomplete.

Providing explanations, the addition of subprograms to calculate averages and standard deviations, error counting, and graphics were identified as necessary modifications during the evaluation process to be added in the delivery system.

Although the ADIS system was found easy to use, users were concerned that their attention would be divided between working with a client and working with the system. Much of the rehabilitation engineer's attention must be focused on observing the client's performance, effort level, and motor control while performing the tests. However, the advantage of the ADIS system's ability to explain its reasoning along the assessment path was expected to be a valuable tool in real-time decision-making. At this stage of testing, the system appeared to be more useful as a tutorial for therapists in training rather than a real-time clinical tool.

CONCLUSIONS:

The validation of ADIS has identified useful modifications to improve the system, namely adding deeper knowledge that reflects more decision alternatives, and increasing the overall utility and user-friendliness of the system. During the final phase of the validation, ADIS will be tested by novice users in training. Future revisions to accommodate feedback from testing, and improvements to the hardware interface components should prove ADIS useful as an evaluation tool as well as fully demonstrate the utility of ADIS as tutorial software.

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A TEXT DATABASE AS A COMMUNICATION PROSTHESIS

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ABSTRACT

A text database is being used as the basis for a communication prosthesis. The database enables text items (words, phrases, paragraphs and extended narratives) to be stored and accessed. An interface module gives a handicapped user efficient access to stored text. Text items are designed to model conversational units and therefore allow the user to take part in extended conversational discussions. Text can be composed and modified using an integral editor.

COMMUNICATION AND CONVERSATION PROSTHESES

Communication systems (1) have been developed which attempt to facilitate and accelerate communication for handicapped persons, who may be restricted to effective word rates of less than 10 words/minute (w/m). Predictive strategies (2,3,4) and other devices (5) have been proposed; a typical predictive system on a current microcomputer might cut typing workload by half (4). Much greater improvements are needed, however, to increase word rates from under 10 w/m to the norm of 120-200 (spoken) w/m. The authors developed a conversation support system called CHAT (6), which assists a user to perform communication acts, and has:

1) a dialogue model, based on discourse analysis, to exploit the patterns in human dialogue;

2) a set of pre-composed stored phrases representing a wide range of conversational acts;

3) a simple & highly efficient user interface;

4) an editor to create, alter & delete phrases.

CHAT contains a large number of stored phrases appropriate for most sections of normal dialogue, but the dialogue phase which is least predictable, and therefore least amenable to the CHAT strategy, is the "Main Topic". It is difficult to equip a system with communication acts which will occur predictably in the "Main Topic", but the user should have some strategy for dealing with it. The authors have therefore developed a system which enables a user to create and manage the large amounts of text which "Main Topic" discussion may require.

TEXT DATABASE

Computer databases are used conventionally for the storage and retrieval of large amounts of information, and some are designed specifically for use with textual material. We have investigated current microcomputer database systems, and selected one which has very flexible features, and is particularly suitable as a text database. The relevant valuable features are:

1) variable & unrestricted field & record sizes (for storing text items of different sizes);

2) variable record types (to allow modelling of different types of conversational units);

3) an index system flexible enough to model the inter-relationships of conversational units, but efficient enough for fast item retrieval.

The record format has been designed to model, as far as possible, the components of natural conversation. A piece of text can be retrieved by its topic(s), by the type(s) of speech act (e.g. Greeting, Farewell) it represents, or by words occurring in the text (content) itself.

HANDICAPPED USER'S INTERFACE TO DATABASE

An interface module has been developed to give the user efficient access to the text stored in the database. The interface and database operate concurrently on the computer. The computer display contains a command menu, a menu of text items (each truncated if necessary to fit on 1 display line), and an area which will display, in full, any text item selected from the text menu. A text item may be any word, phrase or paragraph, and extended items may consist of linked paragraphs in the database.

The command menu offers speech act facilities like those in CHAT (6) (e.g. Greetings, Farewells, Requests, Responses and Fillers) but also facilities to allow Topic and Keyword to be specified. Text items in the database can be categorised by topic (each item can have several topic fields). The database can also search the content of every text item for any specified word. The user may thus select a particular topic for discussion, and the database will present a small number (e.g. 5) of items in the text menu. An item may be selected, or further items displayed, at the press of a single button. A selected item will be displayed in full; the user gives final assent by pressing 1 more button (whereupon the item will be transmitted to the dialogue partner(s)) or rejects it by selecting another item.

Topic selection is performed by pressing one command button, then typing the topic name in full or mnemonic form. The mnemonic facility (similar to a technique proposed by Hunnicutt (7)) allows the user to abbreviate flexibly the topic name (e.g. "mc", "micro", and "mcr" could all select the topic "microcomputers").

A typical database access, starting with new topic specification, might require 7 or 8 key-pushes to retrieve and transmit a paragraph of up to several hundred characters. At the other extreme, a "filler" or "feedback" phrase of a few tens of characters may require only 1 or 2 key-pushes. The approximate key-saving ratio of 10:1 which this gives should improve significantly the word output rate of the user. Extended narratives (paragraphs linked together) will increase further this key-saving.

TEXT CONTENT OF DATABASE

The database must contain a substantial quantity of text representing the general conversational interests of the user before it will be of significant advantage. General purpose phrases like Fillers, Greetings and Farewells which were part of the original CHAT system will be present in the database from the outset, but user-specific text (topic material) will need to be added later. The user will use the integral editor in the interface, in his or her own time, to enter new text into the system and modify existing text, thus building up a corpus of useful and personally relevant dialogue material. The user may well prepare for meetings by scripting text in advance; text has already been composed for three diverse topic areas ("religion", "communication prostheses" and "a job interview") in order to exemplify the scripting process. The user's friends, family or facilitator may provide ideas or compose text for the system. The text content of the database will accumulate with time, gradually becoming more useful to the user.

FURTHER DEVELOPMENT OF THE TEXT DATABASE

The composition of new text remains the least efficient aspect of system operation, so continued development of efficient input techniques (e.g. prediction) will be valuable. An editor optimised for the modification of existing text would be very appropriate, to facilitate "recycling" of text. Existing predictive systems (2,3,4) can adapt to the vocabulary of the user; adaptive features could be incorporated so that the database system would optimise its performance to the user, for example by doing frequency-dependent prediction of text items.

CONCLUSIONS: TEXT DATABASE AND COMMUNICATION

A dialogue support system has been developed which incorporates a text database. This enables text to be stored and retrieved by topic or by content, and, in conjunction with an appropriate user's interface, enables a handicapped person to create and manage textual material efficiently, for use in dialogue situations.

ACKNOWLEDGEMENTS

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PRESCRIPTION OF ENCODED NONVOCAL COMMUNICATION DEVICES FOR CONTROL VIA SWITCHES AT MULTIPLE BODY SITES

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INTRODUCTION

The Tufts-MIT Prescription Guide is a computer-based system designed to assist the clinician in selecting an augmentative communication device for a motor-disabled client. It guides the clinician through a sequence of assessments and calculates scores which represent aspects of the goodness-of-fit of each device in the system's data files to the client being assessed.

One of the scores calculated by the Guide is MDM (Motor-Determined Maximum) Rate. This benchmark is an estimate of the upper limit on communication rate the client could achieve with a particular device. It is based on the results of an objective instrumented motor assessment which measures aspects of the client's performance relevant to use of that kind of device. Type 1 and Type 2 assessments, described elsewhere [1,2], provide data for calculation of MDM Rate for planar keyboard and scanning devices, respectively. Type 3 assessment, the topic of this paper, deals with the client's use of a small number of switches placed at useful control sites on his/her body.

RATIONALE AND DESCRIPTION

Assessment

Type 3 assessment measures the time required for the client to alternate closure of pairs of switches mounted for actuation by one or more body parts. Data from Type 3 assessment allows calculation of MDM Rate for encoded devices which may be operated by two to eight external switches of any kind. The assessment is based on the observation that the motoric limit on use of a distributed-switch device is set by the time required between successive switch closures. In each task, the client is asked to alternate closure of two switches, or repeatedly strike a single switch, as quickly as possible. Twenty key strikes are required per task. The maximum number of switches which can be used in this assessment is 8 and the maximum number of tasks is 64, i.e. all possible switch "pairs" including each with itself. A full eight switch protocol typically requires an hour (exclusive of the time for choice of control sites and switch mounting).

Data reduction and MDM Rate calculation

The numbers which are generated by the Type 3 assessment for use by the MDM Rate prediction software are simply the average values of the closure-to-closure times for all pairs of switches. This "model" is simply a lookup table. Because this approach to device control depends on discrete acts at a finite number of sites, use of a lookup table of performance times entails no loss of generality or need for interpolation.

MDM Rate calculation is performed by RATECAL3, a subroutine of the Guide software which operates on two files: the output file from DECOMP3, and the Type 3 assessment results table. DECOMP3 was run for each Type 3 device during development of the Guide (and will be for new devices of that type to update the system). It generates a table whose entries are the frequencies with which switch closure at each input jack is followed by closure at all others. These frequencies are based on decomposition of a 1500 word Standard Text File into the history of switch closures necessary to compose it. This table is referred to as the "jack-pair" frequency table to distinguish between the switches which are associated with client body parts and actions during assessment, and input jacks on the device to which switches will be connected. RATECAL3 calculates average time per switch closure by multiplying the time required for each switch-pair by the frequency of the jack-pair to which it is connected and summing these products. MDM Rate is calculated by multiplying average time per switch by the average number of switch closures per word, also derived by DECOMP3.

Since neither DECOMP3 nor the assessment of the client in any way constrain the connection of the body-distributed switches to the input jacks of a device, RATECAL3 has an additional feature; it performs the calculation of MDM Rate repeatedly in order to determine the mapping from switches to jacks which provides the highest value. If the number of switches (and jacks) is six or less, this optimization is done exhaustively, i.e. MDM Rate is calculated -- in about five minutes -- for all 6! permutations of the switches and jacks. A non-exhaustive search algorithm is used if seven or eight switches were included in the assessment.

PILOT RESULTS AND IMPLICATIONS

20 disabled and 12 able-bodied Ss were assessed with the Type 3 procedures during development of the Guide and additional clients have been assessed in clinical trials since then. Etiologies have included head injury, cerebral palsy, ALS, and other degenerative neurological diseases, and ages ranged from 17 to 56. Switches have been placed for closure by actions of the hands, feet, knees, head, and mouth (breath pressure). In the pilot study, each body part had access to a single switch placed for maximum ease of use. In recent trials, a client has been set up with two switches for each hand.

The pilot study protocol intentionally included, with most Ss, repetition of some or all of the tasks to assess the effects of learning and fatique.

Computation of precise means and standard deviations across disabled Ss and across able-bodied Ss would have little meaning since switch placement differed in critical ways from subject to subject. It is clear, however, that the disabled Ss in this study were considerably slower than the able-bodied. The mean for the former group is aproximately 1 second while the latter has an average of about .3 seconds.

These measured times provide the basis for testing our hypothesis that encoded devices controlled by body-distributed switches could be advantageous in terms of the communication rate they allow. Suppose the following conditions are met:

- the frequency-weighted average switch-to-switch time is 1sec;
- the device offers the alphabet plus highly frequent words in a 64-item language menu;
- 8 switch sites are available so that the selection code requires 2 switch closures per language unit;
- 3 language units are needed on average to compose a word.

These assumptions lead to a time per word of 6sec, or 10 words per minute. It would not be surprising to find that this rate compares favorably with the rates which could be achieved with scanners by the same client.

Data analysis also revealed that for a given subject, the shortest switch-to-switch times could differ from the fastest by a substantial factor. For one group of nine disabled Ss the ratio of maximum to minimum measured average time ranged from 1.5 to 4. These results made it clear that MDM rate can be very sensitive to switch assignment. The decision to include the optimal mapping feature in the MDM Rate calculation was based on this finding.

For the disabled Ss with whom parts of the test protocol were repeated during a single session, data was inspected for evidence of learning or fatigue. Trends were either absent or in the direction of decreasing time. Because of this, instructions were added to the system's User Manual calling for practice with each switch pair before beginning to record data.

The data from disabled Ss is also being examined for qualitative patterns, e.g.:

- When impairment in coordination is a feature of the client's motor picture, it is of interest to compare rate of same-switch tapping by each hand with rate of alternating hand tapping of the same switches.
- Movements of two limbs in patterns which mirror each other are easier to execute than more complex patterns. Data from one client with impaired coordination due to Friedreich's Ataxia demonstrated this effect with significance at the 0.025 level. These effects, if robust, have implications for custom design of device codes and may be of interest as quantitative correlates of neurological symptoms.

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COMPUTER AIDED SPEECH PROSTHESIS

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ABSTRACT

Thousands of people are unable to communicate effectively due to various speech disabilities. The Computer Aided Speech Prosthesis is a portable device which can speak for these individuals. Words and commands needed to build and output sentences are selected from menus shown on a flat panel graphic display. Users can make selections and move through the menus using a single touch switch. The Cyclone provides spoken output via a speaker or telephone line.

INTRODUCTION

Research has been conducted which indicates the large number and varying degree of speech disabilities[1]. A prosthetic speech device can help nonverbal people communicate. Currently available devices fail to meet many of their needs. The CASP consists of a powerful microprocessor controlled system which produces spoken sentences at the control of the user. The innovative approach, which allows the CASP to surpass other devices in speed and flexibility, is the use of a full size screen and a creative menu system to display and select information. The CASP can be adapted to a variety of needs and other uses. It represents the use of recent developments in technology to meet the needs of individuals with speech disabilities.

BACKGROUND

The initial motivation for this design came as a result of personal association with Si Peterson, a young man who suffered a spinal injury which left him paralyzed below the chin. As we met with experts in the field of handicap assistance and speech pathology, we found that there were no devices available that could help Si `speak', and also that thousands share his handicap. Neurological damage due to stroke or injury, neuromuscular diseases, multiple sclerosis, cancer, deafness, and locked-in syndrome can prevent individuals from speaking.

Many of these people have high mental capacity, and are frustrated because they are unable to communicate effectively. A large number could become able to speak with sufficient clarity with training or a supplemental device such as a `talking trach' or voice box, but those for whom this is not possible, a prosthetic device is needed for them to talk.

Work in this area has resulted in many devices. Some,with bliss boards, are portable and simple to use[2], but have limited vocabularies, and require motor skills to press the squares. Others are more powerful, but require a personal computer to operate[3], making them cumbersome or complex to use.

After consultation with many experienced people, and meeting with handicapped individuals to identify their needs, the initial design concepts of a device which fills the current gap were developed. The objective was to develop a system which is portable, has a high quality voice, a large, if not unlimited, vocabulary, and has a telephone interface. The user should not have to spell words phonetically or with morse code, or cycle through the alphabet for each letter. As well, since abilities vary from one individual to another, the system should accept input from various types of input devices. Unless a system is practical to operate, and gives pleasing results, it will not be used.

DESIGN

The CASP consists of several boards on a VME bus mounted in a durable cabinet. A flat panel display and input device are connected by cables. A block diagram of the CASP is shown in Figure 1.

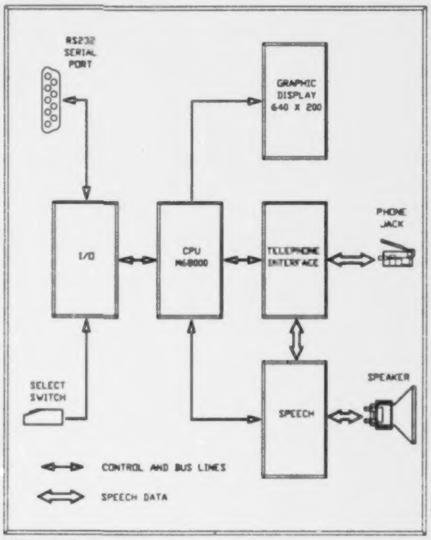

Figure 1. Block Diagram

System Hardware

A Motorola M68000 microprocessor controls all functions of the CASP. The operating system is contained in 16K of ROM memory. 32K of NOVRAM is available for storage of speech and telephone information. This memory is retained when power is off. A serial port is used to down load programs and data from a host terminal during development. Under normal use, the CASP operates independently.

The speech can be output through a speaker, telephone line, or tape recorder jack. The CASP requires 9 watts during operation, and can operate for up to 53 hours on a wheelchair battery, or may be connected to 110VAC. A low battery warning is provided. The CASP is designed to mount on the controlled mounts of any standard Everest and Jennings wheelchair, or to sit on a desk. The cabinet is vented, and protected from weather, spills, and impact.

Speech Synthesis

The speech output by the CASP is generated by Linear Predictive Coding, which is a parameter compilation synthesis method. Digitized speech is analyzed and represented by voice, frequency, and energy parameters. This method once required expensive vocabularies supplied only by the manufacturer; now we develop our own vocabulary. The voice quality is high, and memory requirements are low.

The system comes initially with a 600 word vocabulary. A number of words are easily stored digitally by the user, with a microphone for personal use. One important consideration is the type of voice provided. the user may choose from four voices to suit age and sex. As well, the CASP can be made to speak as easily in any language.

Display

An outstanding feature of the CASP is its high resolution flat panel liquid crystal display. This light weight display has electroluminescent backlighting, and a graphic resolution of 640 x 200 pixels. In the future, picture representations can be used for children or mentally handicapped users.

Control Interface

People with various handicaps are able to use different input devices. The user interface is provided by placing one of several input cards into a slot on the VME bus. Input from a touch or puff-sip switch, joystick, retinal reflection device, or keyboard can be accepted. The unique interface and display system allows the control and selection of a large amount of information with a simple switch. Instead of entering codes or letters, the user responds to displayed information. The input device can be conveniently mounted on a wheelchair or bed.

OPERATION

When the CASP is on, the user sees the root menu from which he can select one of five sub-menus. A cursor moves across the screen at a selectable rate. When the desired selection is highlighted, the user pushes the switch, and that sub-menu is opened. A sample screen is shown in Figure 2. The same process takes place to select a function in the sub-menu.

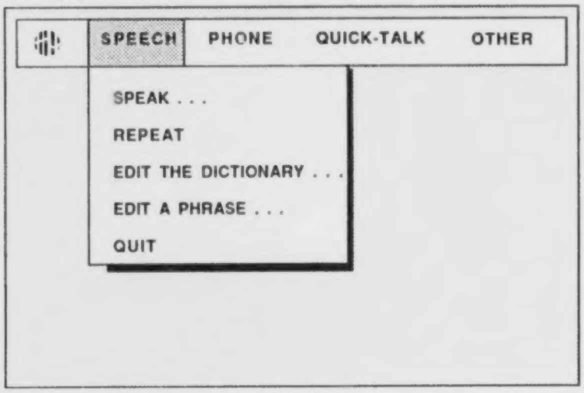

Figure 2. Sample Menu

Using this same principle, the user can move through the system to create and edit phrases, build the dictionary, speak, store telephone numbers, and make calls. The left most menu item is a control box. From here, the user sets the cursor speed, display contrast, and volume. In addition, he can change from a continuously scrolling cursor to one that moves right one selection with each touch of the button.

In the sub-menu, `other' options can be added to do things like controlling lights or heat, or calling a nurse. A `cancel' option is available in each menu. In addition, another switch is provided which always returns the user to the root menu. This menu system is powerful because it combines visual information with anticipated activation of a switch to allow speedy selection. Spatially displayed information is transformed to a time domain. Plus, unlike a bliss board, this display is dynamic and software controlled. It is not necessary to manually change overlays. People with speech handicaps will be able to build and speak phrases quickly with the CASP.

DISCUSSION

In order for the CASP to be of real value, it must be manufactured and marketed. Studies were done on both of these aspects in order to evaluate the feasibility of the CASP.

Market

Statistics Canada's Health and Disabled Survey of 1983-1984 indicates that there are 116,000 people with speech disabilities in Canada. Of these, 4,200 are of a severe enough nature to require a speech prosthesis. One study[4] states that there are 10,000 such cases in the UK, with expectations of 2,000 more per year. In the United States, there is an immediate need of 40,000 with an annual need of 8,000 devices in years to follow. The potential CASP users include individuals, hospitals, research institutions, and education centres.

Feasibility

Since it is a medical aid, and many of its users will have physical handicaps which make accidents likely, the CASP must be made durable and reliable. This, as well as the bus structure and LCD, increase its cost. A cost analysis has been done for the manufacture of 500 units for distribution by an established company. The CASP would sell for $3900. Because of its features and flexibility, the CASP can become the base system for communication, environmental control, and other functions. Given its market potential, the Computer Aided Speech Prosthesis is manufacturable as a special purpose product.

CONCLUSION

Due to the unique design of the Computer Aided Speech Prosthesis, it will allow verbally handicapped individuals to communicate with others much more effectively than they have been able to. The CASP is feasible to manufacture, and there is a significant number of people who can make use of this device. As people are allowed to express themselves in speech, their lives will be changed for the better.

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MODELS FOR SIMULATION OF BIOMEDICAL HUMAN-BODY SYSTEMS

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INTRODUCTION

Modeling, simulation and parameter-estimation is of growing importance for determination of non-measurable parameters and state variables of dynamic systems as well as for case-studies research of biomedical processes have been developed by physicians and system engineers and have also been widely accepted by biomedical scientists. These models already developed have been applied for an extensive analysis of dynamic system behaviour under different conditions by systems simulation. In this way the most important physiologically relevant system parameters have been very often estimated using input and output measurements from experiments on the system itself. However, building of mathematical models is far more involved in biomedicine than in engineering or in natural sciences. This is primarily due to the fact that the mathematical model of a physiological system should describe both, the normal and the pathological state of the system, i. e. the model that can even essentially change the system structure should be valid in a wide range of its parameter values. It is important to note that in biomedical applications in general model building is an essential approach to estimation of clinically important but not directly (e. g. in vivo) measurable system parameters and/or internal system states of interest where even an essential excitation of the "patient under test" system as required for efficient parameter estimation is not allowed for medical reasons.

When developing models of biomedical processes modeling in general entails the utilization of two types of information:

- a-priori knowledge of the process/ system being modeled (the real system must be observable),
- experimental data consisting of measurements of the system inputs and outputs.

But here - not only from a more general point of view - two major facts are of importance when modeling biomedical processes:

- a model always is a simplification of reality but never so simple that its answers are not true,
- a model has to be simple to allow easy handling and working with it.

These are the two relevant boundary conditions for modeling. For modeling is a compromise between model goodness - i. e. the exactness of the results obtained from the model - and expenditure of modeling - i. e. the costs for developing the model, its implementation on the computer and its simulation - which is shown in Fig. 1 [1].

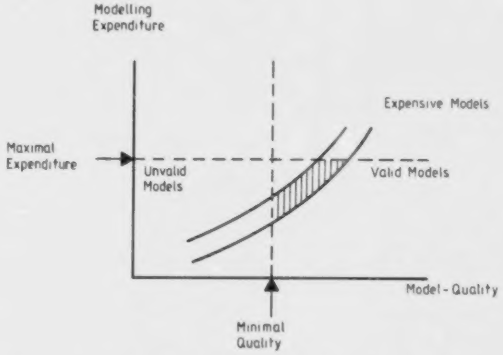

Fig. 1 Dependence on the modeling expenditure (costs) versus the degree of accuracy (model quality)

On the assumption that these dependencies are the common problem arising in model building and simulation, and especially the possibility of applying in a wide range of biomedical system research the same model quality to solve research problems, a class of valid models (referring to Fig. 1) to simulate biomechanical purposes will be described.

MODELS OF BIOMECHANICAL HUMAN BODY SYSTEMS

From a general point of view any human body system can be characterized in terms of its structure, function and performance. As outlined in [2], conventional modeling techniques utilize prevailing knowledge of structure (length, mass, center of gravity, moment of inertia, material properties) and function (knee flexion, knee extension, circulatory function, balance) to develop equations for simulating the dynamics of the system under test.

In order to characterize motion of biomechanical human body systems it is necessary to subdivide the complex task into its components. As pointed out in [2] this process can be simplified by acknowledging a particular kind of sub-system known as a "functional unit". A functional unit is defined as a system or sub-system which possesses only one function.

From this general point of view prosthetic devices - and in this paper we like to restrict ourselves only to this topic - can be divided in subsystems with similar functions. Table 1 shows the sub-systems and their respective functions.

Sub-systems	Function
Hip joint (Articulatio coxae)	Extension/Flexion/Rotation Ball- and -socket joint
Knee joint (Articulatio genus)	Extension/Flexion/Rotation Pivoted lever arm
Ankle joint (Articulatio pedis)	Extension/Flexion/Rotation
Shoulder joint (Articulatio humeri)	Extension/Flexion/Rotation Ball- and -socket joint
Elbow joint (Articulatio cubiti	Extension/Flexion/Rotation Ball- and -socket joint
Wrist joints (Articulatio radiocarpea Articulation mediocarpea)	Extension/Flexion/Rotation
Upper thigh	Brace/Supporting beam/Joint connection
Lower thigh (shank)	Prop/Stay/Joint connection
Upper arm	Lever arm/Joint connection
Lower arm	Lever arm/Joint connection

Table 1 - In brackets the Latin notions -

Table 1 cont.

It is well established that human upright balance can be described mathematically as the familiar pendulum as shown in Fig. 2a. Analyzing the complicated human motion, e. g. of the human arm, it is possible to replace the biological sub-systems by equivalent physical systems. Assuming that the lower arm and hand can be described by only one sub-system as a rough simplification of reality we get in physical notation a double pendulum problem to be solved as shown in Fig. 2b.

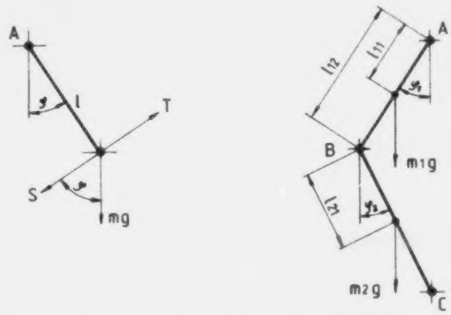

Fig. 2: Schematic representation of biomedical human body subsystems
a) Pendulum equivalent to one joint sub-systems
b) Double pendulum equivalent to two joint sub-systems

The differential equations can be written based on the illustrations shown in Fig. 2. Solving these equations by digital simulation, it is possible to investigate the dynamic behaviour of the developed model, which is of importance with respect to more complex ones like the model shown in Fig. 2b. Moreover the situation results can successfully be used as a reasonable basis for performance specification of prosthetic devices.

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A NEW MULTIFUNCTIONAL HAND PROSTHESIS

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ABSTRACT

A hand prosthesis designed around the essential thumb movements has been developed. This initial version will be used: to validate the prehension geometry and verify the kinematic behavior elaborated with a three dimensional computer aided program CATIA; to evaluate the arm postures and functional characteristics of the available prehension patterns and to test the structural and actuation components.

INTRODUCTION

Opposition represents the essential function of the thumb. Its complex architecture, five degrees of freedom and wide range of opposition, characterizes the manipulative dexterity of the thumb. Obviously, dexterious interdigital manipulations, such as those required for translation or rotation of objects, are still beyond the reach of the actual prosthetic technology. However, if the objectives are limited to actions such as picking-up, holding and efficient utilization of commonly used objects, this goal can well be attained provided that the hand is designed around the thumb's essential movements. These movements which belong to the two degrees of freedom associated with carpal-metacarpal joint are recognized as giving the thumb its governing role during prehension.

The geometry and kinematic behaviour of the new hand prosthesis have been defined following the results obtained from an ergonomic analysis of arm and hand postures during the grasping and utilization phases of objects of daily living (1). This analysis has shown that the thumb uses a prefered plane of flexion which intersects the palmar plane with an angle ranging between 45 to 55 degrees. For an angle of 45 degrees the tip opposes the web separating the last two fingers. This prehension geometry has been further developed and verified with the aid of a three dimensional computer graphics application program called CATIA (developed by Dassault Systems (2)).

ARCHITECTURAL DESIGN

The architecture and the geometry of the hand prosthesis have been developed on CATIA as a function of the specified functional requirements and of the prehension patterns selected (3). For the fingers, three predefined flexion positions have been used as a reference. They are: 1. the functional resting position which here corresponds to the hand open position; 2. the most frequently used tridigital (palmar) prehension and 3. its useful complement, the lateral prehension pattern. Designed around the above prehension patterns, this hand prosthesis is however, with the thumb plane of flexion at 45 degrees, geometrically well adapted for cylindrical and spherical grasping functions. This applies also to the hook and the powder grip which can be obtained with a slight delay of the thumb flexion.

For all prehensile activities, the thumb is actively flexed at the level of the carpo-metacarpal (CMP) and of the interphalangeal joints (IP). With two degrees of freedom, the CMP joint is active in the plane of flexion and passive in the orthogonal plane of adduction and the MP joint is flexed at a fixed angle of 10 degrees.

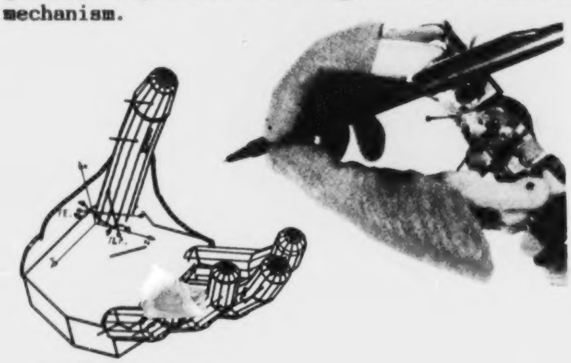
For a prosthetic hand, the palm is probably the most compromized component. With the natural hand, it is an active prehensile structure but with the prosthesis this role is passive. However, in order to meet our geometrical and functional requirements, the following characteristics have been used for the design:

- A morphology resembling and based on the dimensions of the natural hand.
- The MP joints of the fingers describe a dome curve in both the transversal and longitudinal plane of the palm.
- The MP joints oriented to spread the fingers apart during extension.

Besides its passive structural role, the palm encloses the motor and gear assembly which through an adjustable clutch drives the two cross shafts. The shafts are mounted with five concentric spring loaded pulleys to which, the cables mobilizing the fingers are connected.

The design of the fingers is conditionned by the thumb line of action. Some of the functional characteristics include:

- A prehension based on four fingers actively flexed at the level of the MP and proximal IP_1 joints, with the distal IP_2 joints are flexed at a fixed angle of 30 degrees.
- The thumb and finger segments are mobilized through a spring loaded mechanism that allows independant adaptability for each finger.
- The initial flexion and the rate of flexion increases when going from the index to the little finger (see Figure 1).
- The finger flexes when pushed by external forces.
- The finger's rate of flexion approximates 11.8 cm/second
- The maximum opening between the tips of the thumb and Index finger is 9.5 cm.
- The tridigital and lateral prehension are obtained with the same angles of flexion of the phalanxs (see Table 1). This finding has greatly simplified the design of the actuation mechanism.



Hand in open position (CATIA)

CMP Axis FE. - flexion - extension
A.A. - adduction - abduction

HAND OPEN AND TRIDIGITAL PREHENSION

TABLE 1: Joint angle of phalanxs in degrees for different patterns (CATIA)

Finger	Joint	OP	Tri.	Lat.	Close	Notes
Thumb flexion	CMP (1)	8	27	28.5	8	MP fixed at 10 degrees
	IP	10	33	33	10	
Thumb abduction	CMP (1)	25	25	59	25	
Index flexion (2)	MP	10	53	53	77	
	IP1	20	49	49	80	
Middle "	MP	15	61	61	80	IP2 fixed at 30 degrees
	IP1	20	48	48	80	
Ring "	MP	20	60	60	80	
	IP1	20	65	65	80	
Little "	MP	20	66	66	82	
	IP1	20	67	67	82	

1 = CMP. Zero degree is normal to the palmar plane
2 = Measured between finger segments at the joint
OP = hand open, TRI = tridigital, LAT = lateral

FUNCTIONAL EVALUATION AND RESULTS

A preliminary functional evaluation test has been carried out in a laboratory setting. The methodology employed consisted of an analysis of the prehension performance and arm positioning during the administration of three upper extremity functional tests. These were; the Smith hand function evaluation, the Carrol upper extremity function test and the Minnesota Rate of Manipulation test. The performance analysis was based on a comparison between the new hand and the well known Otto-Bock hand and was carried out by wearing alternatively both hand prosthesis. In the above tests, manipulation speed is to a great extent used as a measure of the manual dexterity. In this first analysis we have preferred to concentrate our attention on the more pertinent observations such as those relating to arm-hand posture, quality of prehension and object manipulation. The results obtained from this analysis allow the identification of the following functional advantages of the new hand:

- it minimizes the use of body and arm compensatory movements during all the phases of prehension. This is particularly evident for the tasks performed above a table or a shelf; where the Otto-Bock hand must approach the objects from above i.e. the forearm nearly verticalized.
- greatly improves the visibility over the object
- allows a better orientation of the object held for use
- improves the stability and cosmesis of the grip function.

ACKNOWLEDGMENT

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MICROCOMPUTER-BASED MUSCLE SITE IDENTIFICATION FOR ELECTRODE PLACEMENT IN MYOELECTRIC PROSTHESES

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OBJECTIVE

The overall objective of the Powered Upper Extremity Research and Development Program at the Hugh MacMillan Medical Centre is to increase and enhance the utilization and of powered prostheses through the improvement of the amputee-prosthesis interface. To this end, one of the primary challenges facing developers of myoelectric prostheses is to increase the ratio of the myoelectric control signal to the interference signals from sources such as power lines, neighbouring muscles and motion artifact. Similarly, the objective of a clinician in selecting sites for electrode placement in myoelectric prostheses is to maximize this ratio by selecting the site which consistently exhibits maximal myoelectric activity and minimal cross-talk from neighbouring muscles. The objective of this project is to develop a valid, reliable and expedient clinical tool for identifying the optimal site for electrode placement in myoelectric prostheses.

BACKGROUND

Current Procedure

To identify the site of maximal myoelectric activity, the therapist typically probes the amputee's residual limb with an analogue voltmeter and, through trial-and-error, searches for the site where the largest, most consistent myoelectric signal can be detected. The procedure is then repeated on the antagonist muscle. The identified sites are then checked for cross-talk.

Problem Statement

There are a number of difficulties associated with this method of muscle site identification:

1) The determination of the site of maximum myoelectric activity may be erroneous since the amputee may vary the force of contraction as the probe is moved from site to site. Although the amputee is instructed to maintain the same level of contraction throughout the session, this is very difficult to achieve.

2) In cases that the signal is low or interference from other muscles is significant it can take several hours to identify the site.

3) There is no objective standard for deciding how much cross-talk is acceptable. In a myoelectric prosthesis cross-talk from antagonist muscles is acceptable if the cross-talk signal plus the noise is unlikely to exceed the voltage threshold for turning on the prosthesis. The therapist, however, is not aware of the precise voltage threshold and may, therefore, not make a accurate decision regarding the acceptable level of cross-talk.

MICROCOMPUTER-BASED METHOD

The microcomputer-based muscle site identification system consists of a multi-electrode probe, signal processing hardware, an analogue to digital converter and a microcomputer. The analogue hardware, similar to that used in myoelectric control amplifies and filters the signal and outputs the RMS of the signal averaged over 30ms. To minimize the variance of the control signal, it is further averaged digitally by the microcomputer. Using the multielectrode probe illustrated in Figure 1, the system represents the magnitudes of the mean bipolar myoelectric signal from four electrode pairs (1-2,3-4,5-6 and 7-8) as vectors (Figure 2). The difference between the signals detected by

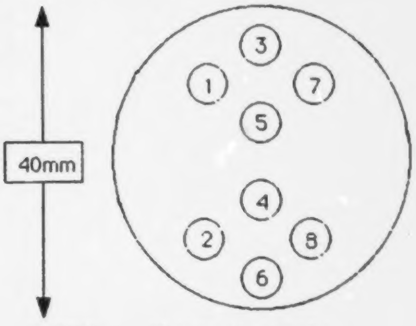

FIGURE 1. Electrode Probe

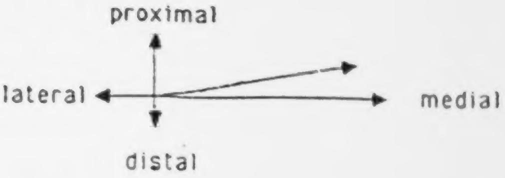

FIGURE 2. Computer Display

electrode pairs 1,2 and 7,8 approximates the partial derivative of the myoelectric signal with respect to variations in the medial-lateral direction and the difference between the signals detected by pairs 3,4 and 5,6 approximates the partial derivative with respect to proximal-distal variations. These two partial derivatives comprise the medial-lateral and proximal-distal components of the resultant vector respectively and represent the direction of maximum increase in signal level. If the probe is iteratively moved in the direction of this vector, it will eventually converge on a local maximum. This method of locating the myoelectric signal maximum is equivalent to Cauchy's numerical technique for optimization of functions of many variables(1).

To use the system the therapist first identifies an allowable region on the amputee's residual limb, based on practical and prosthetic considerations, for placing the electrodes. The probe is then placed on the perimeter of the allowable region and the amputee is asked to contract comfortably. The measured vectors and resultant are displayed to the therapist on the computer screen. The therapist follows the vector until the system converges to within 1cm of the maximal site. It is possible, in theory, that more than one local myoelectric signal maximum exists within the allowable region(2). To detect multiple maxima the therapist can repeat the procedure by choosing various starting points for the probe on opposite sides of the allowable region. In clinical practice we have found that the allowable region is small enough to exclude the possibility of multiple maxima.

To test a site for cross-talk acceptability, the probe is placed on the agonist muscle and the therapist asks the amputee to contract the agonist comfortably for 2 seconds. The mean, minimum, and maximum of the signal level are presented on the screen as an analogue display. The amputee is then asked to maximally contract the antagonist muscle and this signal is similarly recorded on the screen. If the mean agonist signal is greater than the maximum cross-talk signal, the selected site is acceptable. If the site is unacceptable due to cross-talk, the vector display of Figure 2 can be used, this time measuring cross-talk due to the antagonist muscle, to move the probe away from the direction of cross-talk detection.

The system has several features which facilitate the procedure described above. Since the system compares myoelectric signals from four channels, the gain of each channel must be closely matched. The system automatically calibrates the gains of the four channels in software based on a reference signal included in the analogue hardware. The system also allows the therapist to scale the display to the magnitude of the amputee's signal and to adjust the averaging time of the software averager. The therapist can increase the averaging time to filter out very short muscular contractions which are inappropriate for prosthetic control and hence base the selection of muscle site on consistent maintainable contractions. Alternatively, the averaging time can be decreased for cross-talk measurement to ensure that the system detects all signals that would be detected by the prosthetic control system.

RESULTS

The muscle site identification system has been installed in the HMMC Powered Upper Extremity Service Delivery clinic and has been successfully used, in conjunction with traditional techniques, on 11 amputees to date. A therapist familiar with the operation of the system can identify an appropriate site in less than 10 minutes.

Since one of the objectives of the muscle site identification system is the improvement of the amputee-prosthesis interface, evaluation of the system requires an objective method of tions evaluating the efficiency of the interface. To this end a Myoelectric Control Assessment Program (MCAP) has been developed at HMMC (3). This program will be used to test the hypothesis that the more objective muscle site identification technique outlined here will result in better functional control for amputees who use myoelectric prostheses.

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EXTENDED PHYSIOLOGICAL PROPRIOCEPTION FOR THE CONTROL OF ARM PROSTHESES

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INTRODUCTION

While direct neural control of upper-limb prostheses (1) may be an ideal long range goal, practical control methods have been limited to utilizing the mechanical or electrical effects of neural action. Although many innovative control actions have been explored, there are only two that are presently in widespread use: relative body motion and myoelectric signals. The former is used extensively to control body-powered prostheses and the latter exclusively for externally-powered devices.

This paper describes a method utilizing relative body motion to control externally-powered above-elbow (or higher) limbs in a way which maximizes position feedback. Advantages and disadvantages are discussed, as well as means for implementation.

CONTROL METHODS

Relative body motion

The most common configuration of this control method is the dual-control prosthesis, worn by the vast majority of above-elbow prosthesis wearers. A harness provides both suspension of the prosthesis and tension in control cables to actuate the prehensor or flex the elbow, depending on the state of an elbow lock, triggered by a second body motion.

In the elbow flexion mode, this may be termed "position control", because the position of the elbow has a one-to-one correspondence with input cable excursion. Variable control of velocity is obtained by varying the rate of input excursion.

The main advantage of this method is the inherent position feedback which can be sensed by the amputee through proprioception. This significant position sense is what enables unimpaired individuals to touch their fingertips behind their backs without visual cues. The main disadvantage is that cable tension must be present to maintain a flexed elbow angle, unless an auxiliary lock is provided.

Myoelectric signals

This control method uses high-gain amplifiers, usually with skin electrodes, to sense the electromyographic (EMG) signal proportional (not necessarily linearly) to the force of muscle contraction (2). This signal then usually activates an electric motor with proportional velocity. For elbow control, this may be termed "velocity control" since the velocity of the prosthetic joint is proportional to the measured EMG signal.

The principal advantage of velocity control is that the prosthesis will come to rest wherever it is with zero input. The disadvantage is that there is no inherent feedback of joint position, so supplemental pathways, such as visual or auditory, must be relied upon.

EXTENDED PHYSIOLOGICAL PROPRIOCEPTION (EPP)

This term was coined by Simpson for the position control method he devised for pneumatic total arm prostheses developed in Scotland for amelic and phocomelic children (3). He likened this concept to the ability to extend proprioception into inanimate objects such as tennis racquets or hammers.

The conventional dual-control prosthesis is one example of a system using EPP. It seems likely that one of the reasons for the widespread popularity of this system is the proprioceptive feedback it provides.

IMPLEMENTATION OF EPP

As shown in the figure, there are three essential components of an EPP system for a powered prosthetic joint:

Input

The input signal is usually generated by tension in a control cable, similar to the body-powered dual-control prosthesis. However, whereas up to 7.5 cm. of excursion and 200 N. of force may be required for conventional systems, considerably less is needed for EPP. Therefore, the cable and housing can be significantly smaller. The housing we use, for example, has an diameter of 1.8 mm. An input signal can also be generated by compression, such as motion of the acromion inside a rigid shoulder cap.

Transducer and electronics

Any device which can convert force or displacement into an electrical signal can be used, including strain gages, force-sensitive resistors (FSR's), etc. Proportionality is desirable, but on/off systems have been built. An appropriate electronic circuit converts the transducer signal into a motor control signal to drive the prosthetic joint.

Feedback

A vital component of an EPP system, mechanical feedback makes the system, in Simpson's terms, "unbeatable". As opposed to a conventional servo system, the input is constrained by the output and can be sensed by the amputee. For example, if the elbow flexes against an impediment, it will stop and the amputee will sense the restriction of motion in the cable, in addition to the forces and moments in the socket.

Our version of EPP utilizes a pulley at the elbow to provide the feedback signal. The advantage of this configuration is a linear relationship between elbow angle and feedback excursion. Childress (4) attaches the feedback cable directly to the forearm, sacrificing linearity but gaining simplicity.

The version of EPP shown derives its signal from flexible tension-only harness elements. Therefore, this system has, in a strict sense, EPP only in the flexion direction. True bidirectional EPP would require harnessing which could generate tension in an opposing direction as well. It is not clear if the benefits gained would be worth the complexity.

CURRENT WORK

We are currently implementing EPP on two electric above-elbow prostheses: the Utah arm and the Boston elbow. For the Utah arm, we utilize a strain gage transducer located at the control site with a long feedback cable passing through a miniature housing. Because the system was designed to be controlled myoelectrically and the electronics are packaged in a sealed hybrid unit, additional circuitry is required to convert the transducer signal into a synthetic EMG signal.

The approach for the Boston elbow is somewhat different. Our transducer is a small optical sensor located immediately above the elbow, with the input cable routed from the harness to it in a conventional manner. Again, smaller, more flexible, cable and housing can be used because the forces involved are considerably less.

We plan to fit the arms to an amputee subject in the laboratory, who will perform tracking and positioning tests to quantify system performance.

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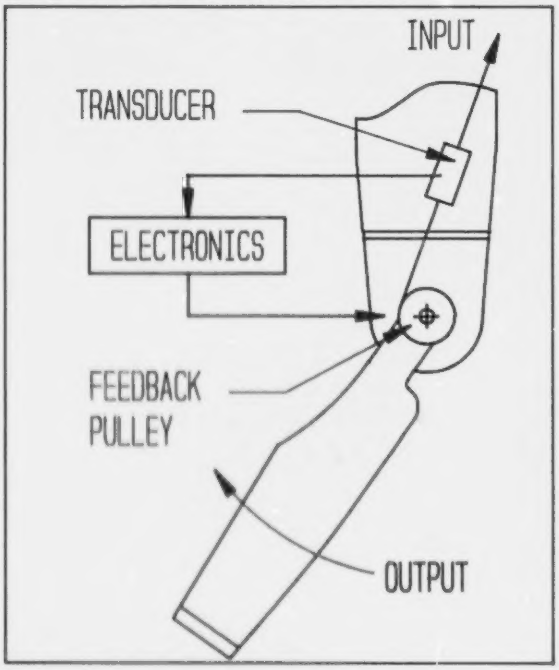

DEVELOPPEMENT D'UNE ORTHESE ACTIVE DES MEMBRES INFERIEURS

Hiroyuki Miyamoto, Toshio Numao*, Kiyoshi Ueda*, Akira Sano*, Shinsaku Mori* et Yasuhisa Sakurai

INTRODUCTION

Les moyens de locomotion tel qu'un fauteuil roulant ne permettent pas la restauration de la fonction de locomotion chez les personnes handicapées à la suite de maladies ou d'accidents. De plus, se mettre debout, marcher sont des motivations profondes pour les paraplégiques et au point de vue physiologique, la verticalisation et la mobilisation des membres inférieurs sont très profitables pour le patient. Nous présentons dans cette communication, un deuxième prototype d'orthèse active des membres inférieurs, commandée par micro-ordinateurs, avec des essais expérimentaux de l'ambulation motorisée. Notre première orthèse avait des inconvénients suivants: les matériels tels que la pompe hydraulique et l'électronique de contrôle étaient trop grands et lourds pour l'utilisation pratique. Huit tubes assurant la canalisation de fluide entre l'orthèse et le wagon de contrôle étaient encombrantes et gênantes lors de l'ambulation.

METHODE

Le système complet de l'orthèse active se comporte de deux parties: l'orthèse elle-même revêtue par le patient, et l'unité de source hydraulique et de contrôle installée dans un wagon qui se déplace avec le patient comme le montre la figure 1.

Orthèse L'orthèse en plastique renforcée par fibre de carbone est articulée aux hanches, genoux et chevilles, avec un degré de liberté. Un corset moulé en polyéthylène, fixé à l'orthèse au niveau des hanches, limite les déplacements du tronc dans le plan sagittal. Hanches et genoux sont motorisés par des actionneurs électrohydrauliques, de type digitaux. Les chevilles restent libres et equipées d'une limitation de la flexion plantaire.

Actionneurs Un actionneur électrohydraulique a été développé pour cette orthèse: les mouvements sont pilotés par un moteur pas à pas lors qu'une position est donnée comme signal numérique. Les actionneurs sont incorporés dans l'orthèse au niveau des cuisses et jambes.

Capteurs Trois sortes de capteurs sont employés sur cette orthèse: 1) Des codeurs optiques incrémentaux donnent l'angle relatif des articulations. 2) Des semelles dont la résistance électrique varie en fonction de la pression permettent de détecter l'instant de l'attaque du talon et du décollement des orteils. 3) Deux capteurs d'inclinaison, situés au corset, sont utilisés pour la mesure et le contrôle de l'inclinaison du tronc, tant dans le plan sagittal que dans le plan frontal. Ces capteurs servent de gyroscope, avec l'avantage de donner l'inclinaison absolue du tronc, sans être influencé par l'accélération[1].

Contrôle Pour le contrôle de l'orthèse, un micro-ordinateur KXT-11/AB de DEC gère l'ensemble des mouvements de l'orthèse, tandis que six micro-ordinateurs de type Z-80A, sous le contrôle de celui-là, mesurent l'angle relatif et contrôlent les actionneurs des hanches et genoux dont le diagramme est donne dans la figure 2. Comme le contrôle de l'articulation est fait complètement en boucle fermée et en local, il suffit de fournir un angle d'articulation souhaité à chaque ordinateur esclave. La liaison entre ces ordinateurs sont faite en signaux digitaux. Seule l'information sur l'inclinaison du tronc se passe par un convertisseur analogique/numérique.

Commande de l'orthèse active On est amené à utiliser des séquences prescrites pour générer les mouvements de chaque articulation. On a donc recueili expérimentalement les trajectoires angulaires des articulations d'un sujet valide marchant en sol plat et à vitesse stationnaire, à l'aide d'une orthèse de mesure. Ces trajectoires ont été analysées et représentées par une série de courbes de spline cubique: avec 12 paramètres caracterisant les trajectoires, on peut générer et tailler les trajectoires pour chaque patient, et les vérifier sur un moniteur de graphisme, avant de passer à la séance de la marche motorisée. Au cours de la marche motorisée, elles sont transmises à chaque micro-ordinateur esclave. Le programme résidant dans l'ordinateur principal possède aussi une souplesse de la modification de trajectoires pour avoir une marche mieux adaptée. A cet effet, il suffit de donner des paramètres qu'on peut observer du milieu extérieur, et programme regénère les trajectoires. Dans ce cas, si l'on donne un paramètre défavorable à la marche, le programme ne l'accepte pas, mais il le remplace par un paramètre toléré pour assurer une marche stable. La commande de marche est donnée par un jeu de commutateurs placé sur un rail de wagon: on peut commander "marche" et "arrêt", en choisissant un des modes de marche "pas à pas" et "séquentielle".

RESULTATS

Aux premiers essais, une personne valide est equipée de l'orthèse pour vérifier la sûreté du système total. Ensuite, un paraplégique a essayé une marche motorisée. Le patient se met debout, pieds joints à l'aide du blockage des hanches et genoux. En tenant les rails devant lui, il se tient en équilibre et il donne une commande de marche "pas à pas": le pied droit se met en phase d'oscillation et ensuite le pied gauche se déplace pour reprendre la position debout, pieds joints. Ainsi le patient apprend à marcher à l'aide de l'orthèse active. Pour faciliter la marche motorisée, le patient est demandé de déplacer le centre de gravité du corps sur le pied d'appui par une inclinaison du tronc causé par ses bras.

DISCUSSION

On a monté et testé un deuxième prototype d'orthèse active des membres inférieurs sur des personnes valides ainsi qu'un patient. L'orthèse elle-même se pèse 19.5 kg et le wagon pour l'unité de source hydraulique et de contrôle électronique 68 kg.

Il fonctionne sur un secteur à 100 V à courant alternatif. Comme approche, les séquences prescites pour le début de marche, marche stationnaire et la fin de marche ont été utilisées pour commander des mouvements de l'orthèse. Lors de la marche motorisée, ces séquences sont interconnectées selon la commande donnée par le jeu de commutateurs et l'état de marche. Comme le système complet est devenu peu encombrant par rapport au premier prototype, il nous permettra d'appliquer à celui-ci deux méthodes de commande que nous avons déjà développées sur le premier prototype, et les avons testées sur une personne valide[2].

CONCLUSIONS

D'après des expériences, on peut espérer que l'orthèse active pour les membres inférieurs pourra être un outil de rééducation fonctionnelle pour des personnes handicapées de locomotion. Il est indispensable de développer le système de communication entre l'homme et l'orthèse, pour pouvoir conduire le développement de cette orthèse active plus loin.

REMERCIEMENTS

Les auteurs remercient profondement Professeur N.Akamatsu et Dr.I.Nakajima ainsi que l'équipe du Service de Rééducation du Yamanashi Medical College. Nous adressons nos remerciements à Omori Seikoki, Co., Tokyo, pour son assistance technique. Ce travail a été effectué sous un contrat du Groupe de Promotion des Sciences de la Vie, l'Institut de Recherche de Physique et de Chimie (RIKEN).

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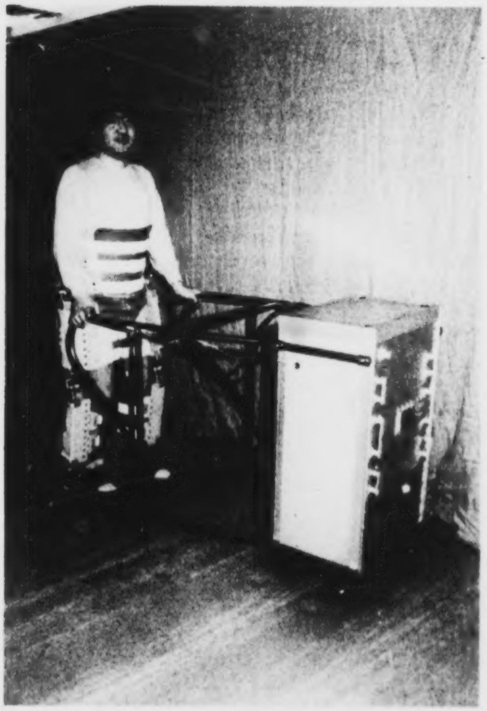

Figure 1. Orthèse active des membres inférieurs

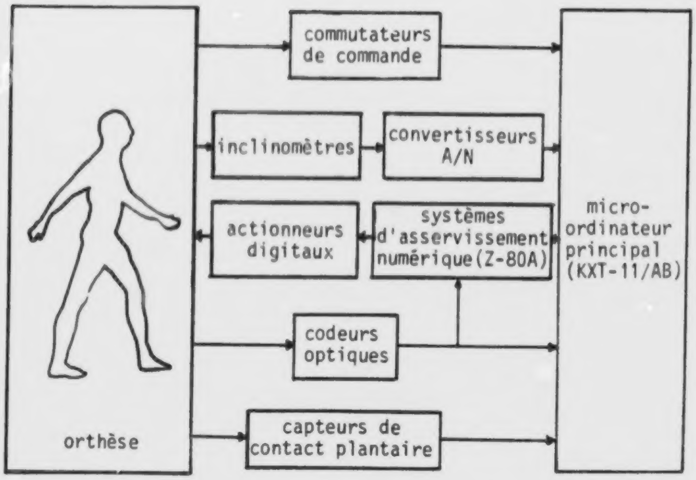
commutateurs de commande
inclinomètres
convertisseurs A/N
actionneurs digitaux
systèmes d'asservissement numérique(Z-80A)
codeurs optiques
capteurs de contact plantaire
orthèse
micro-ordinateur principal (KXT-11/AB)

Figure 2. Diagramme de l'orthèse active

Development of a Lightweight Ankel Foot Orthosis Using Composite Materials

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ABSTRACT

Composite materials were utilized as a replacement for polypropylene in an effort to minimize the weight of an ankle-foot orthosis (AFO). The PC linear ANSYS program was used to determine areas of high and low stresses. Using these results it was possible to develop an AFO using several composite materials of various properties and thicknesses and apply these materials to various sections of the AFO.

Several prototype composite material AFOs were then constructed and tested. While a typical polypropylene AFO weighed 405 grams, an equivalent composite material AFO weighed only 119 grams. A weight reduction of over 70% was thus achieved.

INTRODUCTION

This project was developed due to the need for a light weight ankle-foot orthosis (AFO) to support children with muscle disorders such as cerebral palsy, polio and muscular dystrophy. This project is being developed with Newington Children's Hospital, Newington, CT. The goal is to minimize the weight of the AFO presently used which is formed from sheet polypropylene and is fabricated with a uniform thickness. A lighter weight AFO must have the same functional properties as the polypropylene AFO. The AFO must be rigid enough to support the weight of the patient at the ankle and toe region yet flexible enough to allow for ease of movement.

The lighter weight orthosis is more desirable because as the children grow they must be refitted for larger, heavier orthoses yet their muscles are not able to compensate for this added weight. A lighter weight AFO will provide less muscle constraint to an already weak leg, and permit greater mobility of the patient. With age, the weight of the polypropylene AFO will increase at a much greater rate than that of the high-tech AFO thus prohibiting mobility. Also, by replacing the polypropylene AFO with lightweight composite materials it is possible to vary the thickness while maintaining the strength where necessary. Selective orientation of composite material fibers is possible with composite materials which will allow for a lighter AFO because the fibers provide strength and stiffness in the directions desired.

The overall objective of this project is to produce an optimum minimal weight AFO using the high strength-to-weight characteristics of composite materials. Various material and design considerations will be used to produce an ideal AFO which will provide the necessary support and comfort for the handicapped children at Newington CHildren's Hospital.

MATERIALS AND METHODS

The two appropriate methods for composite manufacturing today are hand lay-up and vacuum bagging. Hand lay-up involves placing the materials on a mold and evenly saturating each layer with resin. The vacuum bagging process is accomplished by using a vacuum system to extract excess resin and to ensure even and thorough wetting of the material. Thorough wetting of the fabric is achieved due to the constant suction that draws the resin through the AFO. Also, due to the transparency of the vacuum bag, the areas needing resin and the areas with an over-abundance of resin could be easily identified. Another benefit is the excellent surface finish that is acquired inside and out giving the AFO a more professional appearance. The process also ensures that excess resin will be extracted from the AFO by the 25 inches of vacuum inherent in the system. This results in a light weight (minimum resin; maximum reinforcement) and at the same time excellent bonding between material types and layers. Finally, through practice, vacuum bagging completion time can be shortened to less than the time necessary for a hand lay-up orthosis, thereby reducing customer cost.

The stresses and forces on the AFO were calculated and compared to the properties inherent in a number of materials. From the data, three reinforcements and one resin were chosen. The first of the materials was polypropylene cloth, chosen because of its low weight and excellent flexibility. The specific gravity was half and its stiffness was one-sixth that of a comparable glass cloth. The second material used was Kevlar 49, chosen because of its high strength and low weight. Kevlar is approximately half the weight of glass cloth and has twice the strength. Glass cloth was used, however, in areas that did not require the strength of Kevlar but at the same time needed to be stiffer than the polypropylene cloth.

The resin selected was a vinylester resin manufactured by Dow Chemical Co. It offers comparable strength to that of an epoxy resin while at the same time being lighter and more flexible than either of them. Hypo-allergenic qualities of vinylester resin also make it ideal for use in skin contacting applications.

Area 1 shown in Figure 1 experienced nominal stresses; therefore, the thickness was not to exceed two layers of polypropylene cloth because of excellent strength properties coupled with good flexibility and weight. The second area was made of Kevlar due to the high stress concentrations that were present at the hole drilled for the strap. One layer of polypropylene cloth was used for Area 3 due to minimal stress but great flexibility was needed for opening and closing the AFO. Area 4 also experienced a low force but required more stiffness than that of the polypropylene; therefore it was constructed of fiberglass cloth. Section 5 experienced high stress levels and therefore required two layers of Kevlar at opposed 45 degree angles in order to maintain flexural stability. Area 6 required strength in an angle 45 degrees relative to the X-Y plane and was made of Kevlar. Section 7 needed only to have strength on the sides of the AFO in order to hold the patients' foot on the device. Finally, Section 8 required flexibility for toe flexion so polypropylene was used in both Sections 7 and 8.

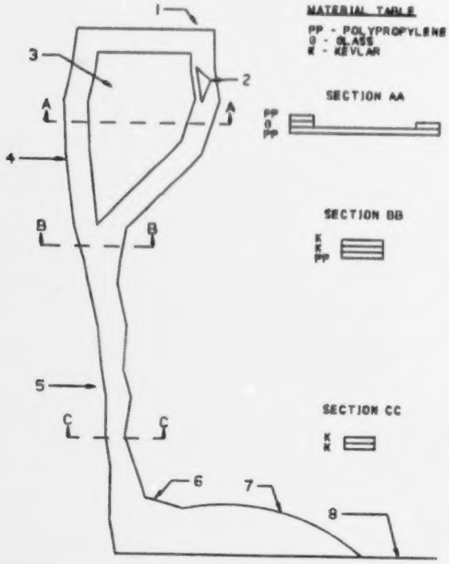

Figure 1

Material Selection Due to Area Stresses

RESULTS AND CONCLUSIONS

The AFO presently used is heat formed from polypropylene sheets with a uniform thickness. The objective of this project was to reduce the weight while maintaining the functional requirements of the AFO. Regions of high and low stresses on the AFO were defined using a PC linear ANSYS program. Composite materials of different strengths and weights were then experimented with and applied to the various stress regions. Thickness was also varied depending on the strengths needed in the different regions and the vacuum bagging method was used to eliminate excess resin thus reducing the weight. This yielded a functional AFO with a weight reduction of 70.5% compared to the presently used polypropylene AFO. A photo and comparable weights of AFOs manufactured using the three design approaches are shown in Figures 2 and 3.

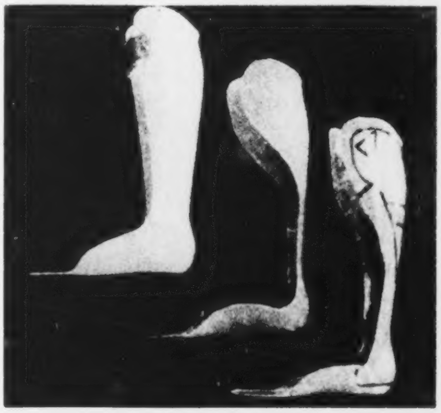

Figure 2

Polypropylene, Fiberglass, & High-Tech Composite AFOs

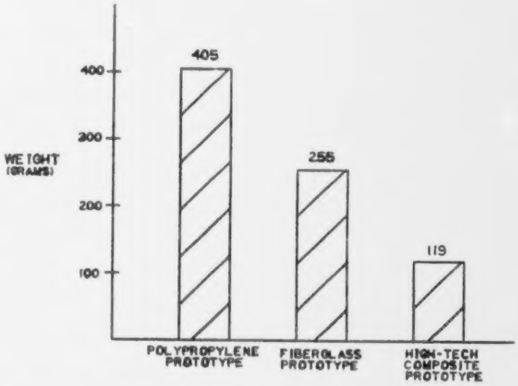

Figure 3

Weight Reduction of Othosis

MECHANICAL FEEDING SYSTEM FOR QUADRIPLEGICS

Marc Filerman

ABSTRACT

To date, the number of affordable personalized mechanical feeding systems available on the market is not keeping pace with the increasing number of severely handicapped or quadriplegic people in the world. This paper presents the design of an inexpensive, portable mechanical feeding device which offers indepedence and dignity for the user. This unobtrusive machine incorporates a movable plate support, mounted on a thin portable tray, with a mechanical arm which serves to bring food from a designated area on the tray to a feeding region in front of the user's mouth. In order to better simulate the normal eating motion, the mechanical arm carries the user's arm. Digital control allows for easy operation and a quick adaptation to the system. A working prototype of the mechanical arm has been built and tested by the designer with success.

INTRODUCTION

The routine tasks which most able-bodied people take for granted, are the very tasks which cause much frustration and anguish for a large percentage of the severely disabled population. Quadriplegics especially, require constant assistance and care, particularly during the act of eating. Hence, there is a great need for an affordable feeding mechanism which would allow a user to eat in public or private, with a minimum of assistance from an outside source.

The design of a personalized mechanical feeding system for adult quadriplegics and the severely handicapped is described in this paper. The device is portable and unobtrusive and thus will allow the user to eat with dignity and respect in a variety of social situations.

DESIGN DESCRIPTION

Concept

Figure 1 depicts an overall view of the feeding system. The hollow Delrin mechanical arm pivots about a horizontal axis and serves to bring the food from a central location on the tray to a feeding region just in front of the mouth of the user. In order to simulate the regular eating motion and reduce the potential embarrassment for the user, the mechanical arm also carries the arm of the eater. The user's elbow rests gently on a padded Delrin support attached to the top of the tray.

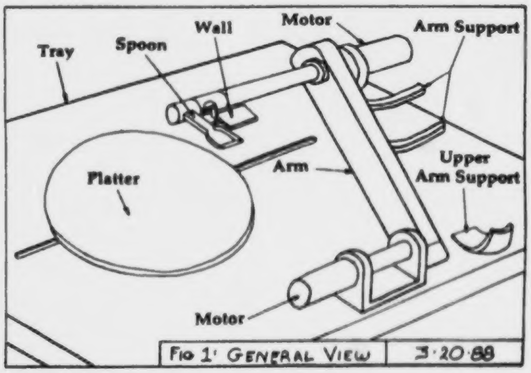

FIG 1' GENERAL VIEW 3·20·88

Mounted perpendicular to the arm are two concentric Aluminum shafts: an inner spoon shaft and; an outer hollow housing mounted rigidly to the arm. The removable plastic spoon is attached to the inner shaft and is controlled by a motor mounted on the far side of the arm. The spoon is complemented with a removable Delrin reaction force wall. Without this wall, the scooper would degenerate into a pusher. In order to ensure that the food stays in the spoon, the wall is torsionally spring loaded against the outer housing.

The mechanical arm is mounted to a hollow Plexiglass tray attached to the user's wheelchair. Also affixed on the tray is a translating, rotating plate support. This Delrin platter is covered a with rubber mat to minimize plate slippage. Since the arm always scoops the food from a set location on the tray, plate motion is necessary if the user is to eat all the food on the plate.

Although the motions of the spoon and mechanical arm are constrained by limit switches to prevent user injury, the device is also equipped with an emergency stop switch.

Control and Operation

Both the motions of the spoon and the arm are controlled with a small, digital feedback control board mounted inside the tray. Hence, the user need only depress one shoulder switch to begin the eating motion. Although these controls are based on the assumption that the user is able to shrug his/her shoulders, the device may in fact be controlled by any one of a number of switches. No feedback control is necessary for the two platter motors since the user will manually position the food under the spoon.

Upon command of the eater, the controller will guide the machine through the eating cycle outlined below. From the rest position, (see Figure 3), the arm first rotates towards the plate. Once the arm is fully lowered, the spoon then rotates towards the wall, scooping the food. In order to prevent the food on the far side of the wall from being pushed off the plate, the spoon is raised approximately two inches before it's rotation is completed.

With the spoon/ wall assembly now horizontal, the arm raises and presents the food to the eater. Since the positions of the spoon and mechanical arm are sensed with two encoders, mounted discreetly inside the arm and tray respectively, the spoon/wall assembly is held horizontal during the arm's rotation toward the user. The wall is retracted by means of a cable grounded to the tray, (see Figure 4). One final depression of the shoulder switch causes the arm and spoon to return to the rest position.

EXPERIMENTAL RESULTS

A prototype of the mechanical arm has been built by the designer (see Figures 2 and 3). The dynamics of the system are now being evaluated using manual control of the arm (grey control box in Figure 2). However, the prototype is soon to be micorprocessor controlled.

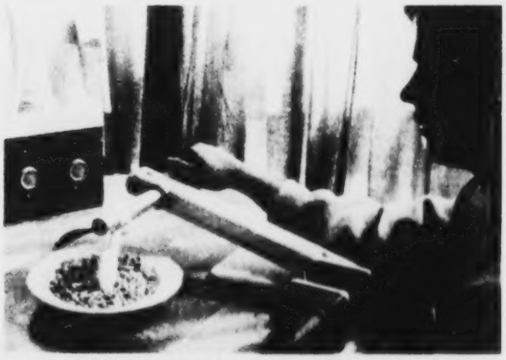

Fig. 2: Complete View of Prototype

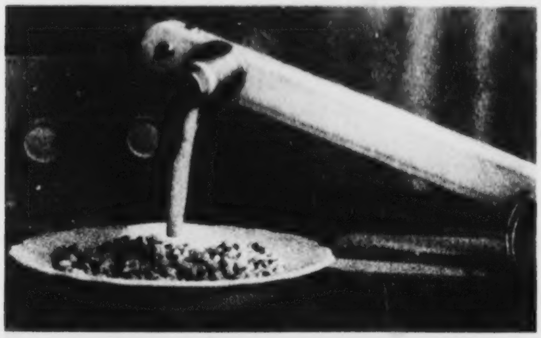

Fig. 3: Side View of Arm, Showing Spoon/Wall

Mechanically, the prototype functioned as designed. The clamping force between the wall and the spoon was found to be sufficient for a variety of foods and the wall retracted far enough to never interfere with the eating process (see Figure 4 below). On average, one complete eating cycle per spoonfull was found to take just under eight seconds.

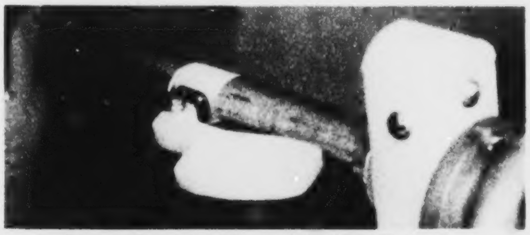

Fig. 4: Close-Up View of the Wall Retraction

While this prototype has not been tested on actual quadriplegics, other subjects have reported that the device feels quite natural. Although minor alterations in certain dimensions, such as the length of the mechanical arm and/or spoon shaft, will need to be made if the sysem is to accomodate a variety of users, this first prototype has successfully demonstrated the design concept.

CONCLUSIONS

The design presented in this paper has been motivated by the belief that an affordable personalized feeding device which enables the user to consume food with dignity, ease and a minimum of assistance from an outside source, should be available to every quadriplegic and severely handicapped person.

This design offers advantages not found in some other feeding devices. First, the unobtrusive nature of the device will allow a quadriplegic to eat with dignity and respect, even in a public environment such as a restaurant. As quadriplegics are handicapped only physically, these two qualities were held paramount throughout the designing process. Second, the natural motion of the device will provide unencumbered feeding assistance and reduce the potential embarrassment for the user. Finally, the system is portable and easy to use for the operator. The one touch control switch used to actuate the mechanical arm allows a new user to adapt quickly and easily to the device.

Thus far, no mention has been made about the cutting of the food. However, a student design team at M.I.T., of which I was a part, has completed the preliminary design of a circular cutter which mounts to the tray on the far side of the platter. This type of cutter could be installed with relative ease, thus alleviating food cutting problems.

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EFFECTIVENESS OF CERVICAL SPINE STABILIZATION DEVICES MEASURED BY ACCELEROMETRY

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A.P. Sumchai, C. Hargis, Stanford Univ. School of Medicine, Dept. of Surgery/Emergency Medicine

INTRODUCTION

Very little is known of the acceleration and vibration experienced by acute cervical spinal cord injury (SCI) patients, despite widespread recognition that movement of the head relative to the body could have severe neurological consequences */1/*. Procedures and apparatus have been placed into common practice with the intention of stabilizing the damaged spinal column by immobilization and/or traction, without knowledge of their efficacy under dynamic conditions */2/*.

BACKGROUND

Spinal Stabilization Following Injury

In early treatment of a SCI patient, effort is made to restore and preserve vertebral alignment, both by immobilization using spineboards, collars, straps, sandbags and other forms of restraint */3/*, and by traction applied by skeletal tongs attached to weights */4/* or to constant-force springs */5/*. Two radiographic studies on supine */6/* and sitting */7/* normal subjects demonstrated maximum cervical immobilization by strapping to a short extrication board, with collars yielding little if any advantage alone or combined with the board. Neither study provided quantitative data on forces causing radiographic displacements, nor did they investigate dynamic loading.

A new device intended for pre-hospital use, the "TACIT", is being developed by Minto Laboratories, Redding, CA. The TACIT is a short spineboard with width-adjustable foam-padded head supports capable of applying traction via the zygomatic arch and occiput. Traction (up to 30 lb) is dependent on patient position, so patients are fixed to the board by a jacket having shoulder and leg straps. The device is made of molded glass-filled thermoplastic and has been tested for cervical spine motion by MRI scan */8/*.

Accelerometry in Biomechanics

Morris */9/* advocated accelerometry for gait analysis, using five single-axis semiconductor accelerometers mounted on a platform on a tibial cast Data compression was performed by manually selecting a 2.6 sec interval of taped output for digitization at a 100 Hz rate. More recently, Farris */10/* reported on the use of a single 3-axis piezoelectric accelerometer located at the posterior pelvis tethered to a fixed computer.

Whether motion measured at the skin corresponds to skeletal motion is a question applicable to virtually all non-radiographic methods. Where a bony landmark exists, as on the medial tibia, attaching sensors to a rigid plate on the skin over the landmark gives sufficient (.01 g) accuracy */9/*. Static position of individual lumbar vertebrae can be determined by external direct-contact profilometry with a correlation of about 50% to X-rays; total lumbar spine motion had a standard deviation within ±26% of radiographic methods */11/*. Correspondence in the cervical spine is expected to be better because of the relative prominence of the spinous processes */6/*.

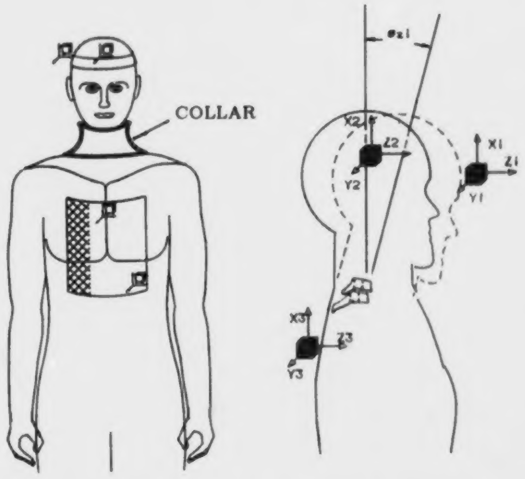


FIGURE 1: Accelerometer Locations

METHODS

Measurements are made using miniature (0.5 inch cube) 3-axis 5-g range accelerometers (Entran Devices, Inc.) taped or strapped to the head and the chest (Figure 1). The difference between the outputs of these sensors is proportional to the rate of change of displacement across the subject's neck. Two 3-axis sensors are placed on the head so as to distinguish torsional rotation. Rigidity of coupling of skin mounting to underlying bone is assessed by comparison to another sensor attached to a bite block. A cable tension transducer (Entran model ELF-1000; 50 lb.) provides an indication of the stability of the traction force, if any.

To date, measurements have been made of procedures that do not involve movement over more than a few feet by a fixed IBM PC-AT computer with internal DACA analog-to-digital conversion boards. "Labtech Notebook" software was used for real-time linearization, filtering, data storage, plotting, and fast Fourier transform analysis. Some procedures are also recorded on videotape synchronized with the acceleration record, using markers on the subject and on equipment under test, so that absolute position can be derived from still video images.

RESULTS

Tests using a single head-mounted 3-axis sensor have been run on the TACIT device and on three types of cervical collars (Philadelphia, "Stifneck" and "Malibu"). Each 120-second run began with installation on a supine able-bodied volunteer, who was then log-rolled 90° to each side, raised to a sitting position one or more times, and asked to exert muscular effort against the neck restraint in compression, in flexion/extension and laterally. Acceleration and traction force for a typical test of the TACIT device are shown in Figure 2. Acceleration for the Philadelphia collar is given in Figure 3. Lacking measurement of gravitational acceleration at the trunk, displacement could not be accurately determined.

CONCLUSIONS

Results of tests on the "TACIT" showed that it could be installed with little (0.05 g) imposed acceleration and provided adequate immobilization of the head, but that traction force was subject to wide fluctuation due to internal friction. All three cervical collars permitted measureable head movement; the Philadelphia collar required lifting the head for installation, resulting in peak flexion/extension (**z**-axis) acceleration exceeding 1.2 g and the "Malibu" collar could not be installed without momentary lateral (**y**-axis) and **z** accelerations of about 0.2 g. These results cannot yet be construed as detrimental to patient welfare.

FIGURE 2: "TACIT" Test Data

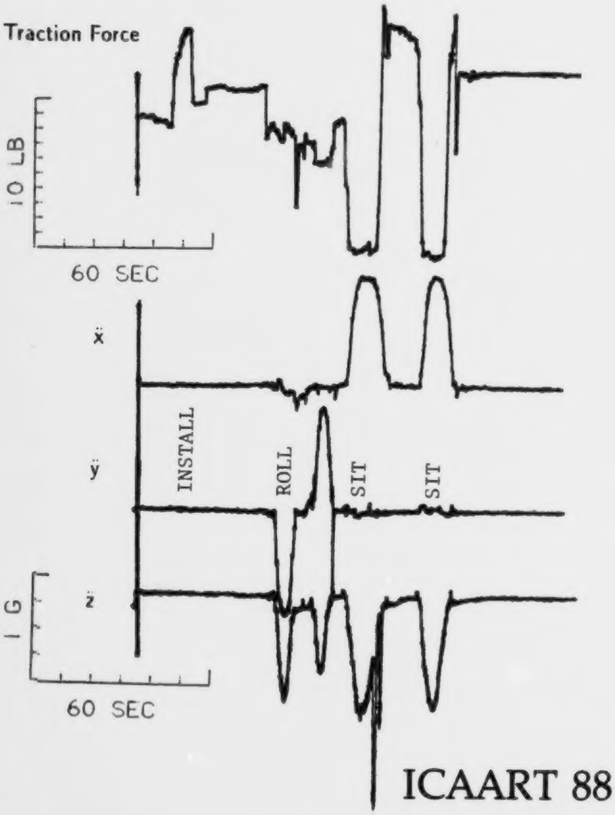
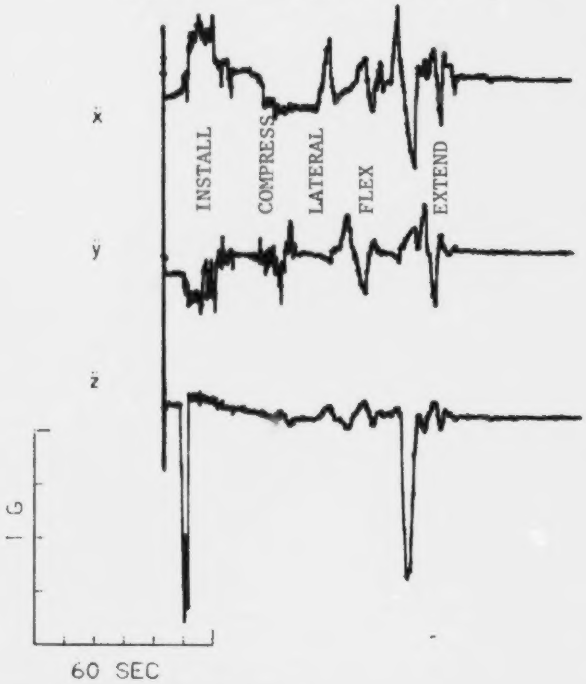


FIGURE 3: Philadelphia Collar Data



ACKNOWLEDGEMENTS

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DEVELOPMENT OF AN IMPROVED MOUTHPIECE FOR A MOUTHSTICK

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Introduction

Advances in medical care have increased the probability of patient survival from traumatic injuries to the spinal cord. Permanent spinal cord injuries result in varying degrees of paralysis. Paralysis which results in the loss of motor control to all four extremities is defined as quadriplegia. Estimates are that currently over 90,000 quadriplegics live in the United States and their numbers are growing.

This article describes the development of an improved mouthpiece for a device used by quadriplegics and others with partial or complete arm and hand paralysis. The device, commonly referred to as a mouthstick is a simple but essential device that allows quadriplegics and others without the use of their arms and hands to perform a variety of routine functions. Without this device, dialing a telephone, typing, or even turning the page of a book is an impossible task. A variety of mouthsticks are currently available; however, no single design has been universally accepted. Each device possesses inherent problems ranging from the inadequacy of the materials selected for its fabrication to the process used for manufacture.

The mouthpiece described in this paper resulted from the collaborative efforts of the University of Mississippi Medical Center Departments of Orthopaedics and Restorative Dentistry, the Mississippi Paralysis Association, and the Materials Science and Engineering Division of the Institute for Technology Development. The final design of the mouthstick was achieved after careful review of existing literature(1-5) and obtaining input from the quadriplegic members of the Mississippi Paralysis Association. The following design criteria were used:

1. The mouthpiece should contact all fully erupted teeth.
2. Biting forces should be distributed to all available teeth.
3. The mouthpiece should have wide occlusal coverage to give lateral stability.
4. The materials used should have good esthetics, taste, texture and should be easily cleaned.
5. The mouthpiece should be inexpensive and custom formable to the user's dentition with minimal assistance.
6. The mouthpiece should be unbreakable and stable in the oral environment.
7. The individual should be able to breathe, wet their lips, and swallow normally with the mouthpiece in place.
8. The mouthpiece should be easily adaptable to accommodate various attachments.
9. The thickness of the mouthpiece after fit should be between 2-4 mm to prevent a gagging response.
10. The mouthpiece should be easily adaptable to changes in the user's dentition.

Materials and Methods

Using measurements of dental arches from stone casts, the dimensions for an average y-shaped mouthpiece were determined. These dimensions were used to construct an injection mold for production of the mouthpieces.

The mouthpieces were injection molded from Surlyn^{TM} ionomer resin using a Morgan Press vertical injection molding machine. Figure 1 illustrates the design of the mouthpiece. The mouthpiece possesses a hollow cylindrical orifice which will accept a solid or hollow rod (diameters between 0.25 and 0.29 inches). The mouthpiece was designed to be compatible with commercial mouthstick kits such as those offered by Fred Sammon's Inc., Brookfield, IL or Abbey Medical Distributors, Bernyn, IL.

To evaluate the mouthpiece design and materials, a simple mouthstick (shown in Figure 2) was fabricated. A graphite-epoxy composite shaft, 16 inches long and 0.29 inches in diameter obtained from Glassforms Inc., San Jose, CA was inserted into the mouthpiece. The shaft was secured in place using a three inch length of heat shrinkable tubing (ICO-Rally, Dallas, TX). A natural rubber pipet bulb (Fisher Scientific, Baton Rouge, LA) was used to cover the end of the shaft and to provide a high friction surface for turning pages, dialing a telephone, etc.

Patient Fitting

In the past, obtaining a custom-fitted mouthstick required a trip to the dental office.

In contrast, this mouthpiece allows a mouthstick to be custom-fit to the user at home in a matter of minutes. The first step is to heat the mouthpiece blank in boiling water for approximately 3 minutes or until it softens and becomes moldable under moderate pressure. Following heating, a brief immersion (3 to 5 seconds) in cold tap water is used to cool the surface sufficiently to prevent tissue injury. The mouthpiece is then placed in the patient's mouth so that it covers all of the teeth. The patient bites down with sufficient force to impress the shape of the individual teeth into the cooling but still soft, plastic material. The impression left by the teeth may range from (0.5 - 5 mm) in depth. The mouthpiece is removed and allowed to cool further until it becomes rigid. The cooling process can be accelerated by placing the mouthpiece under running tap water. Since the mouthpiece material is a thermoplastic, if the fit is unsatisfactory, the process can be repeated until a satisfactory fit is obtained. In addition, the angle of the stick can be adjusted to provide the optimum position for use by the patient.

Evaluation

Five quadriplegics from the Mississippi Paralysis Association were asked to evaluate the mouthsticks before the evaluation period. The average time of use was 4 hours per day. The tasks attempted included turning pages and operating a telephone or computer terminal.

Overall the mouthpiece was well received. A comfortable fit was obtained by all the participants and no problems with taste were encountered. One participant did report a slight irritation to the inside of the cheek, however, the irritation was attributed to a small amount of flash left on the mouthpiece and not to the composition of the material.

The ease of fitting and modifying the mouthpiece to the specific needs of the user were its strong points according to the evaluators. Another particular advantage noted was the durability of the mouthpiece. In one instance a mouthstick was run over by a van without damage. This incident would have been catastrophic for a mouthstick with an acrylic mouthpiece.

Conclusion

A new and improved mouthpiece has been designed, fabricated, and tested. The mouthpiece is fabricated from a thermoplastic resin which can be custom fit to the user's dentition with minimal assistance. This mouthpiece eliminates many of the deficiencies encountered with current mouthpiece designs and materials.

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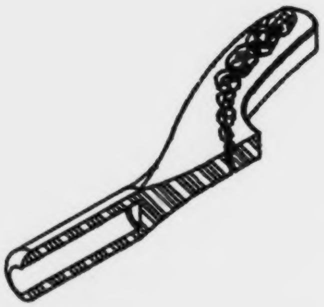

FIGURE 1

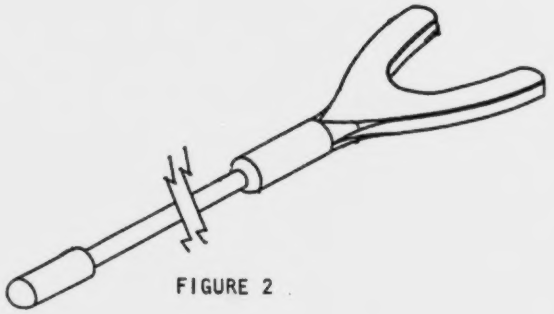

FIGURE 2

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A HYBRID ARM ORTHOTIC SYSTEM

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ABSTRACT:

Wheelchair based, partially body powered and partially motorized, multifunctional arm orthoses for high level spinal cord injury patients is proposed. Four selected upper extremity joints can be manipulated either in sequence or simultaneously in order to cope more effectively with some of the essential daily activities. The design offers the patient voluntary arm functions including prehension, thus improving independency and self image.

INTRODUCTION:

Recent developments in thermo-plastic materials and electronic controls have made it easier to develop powered upper extremity prostheses/orthoses for severely paralyzed spinal cord patients. In recent decades attempts were made to design and develop modular, wheelchair mounted, all electric orthotic systems (1,2,3). The end-products of these efforts, because of their complexity, were limited primarily to university departments or hospitals.

OBJECTIVE:

The objective of this study is to use past experience and new technology to develop an affordable total arm orthosis that is more comfortable to wear, easy to use, reliable, and fully controlled by the patient. The proposed target population consists mainly of high level (C4-5) quadriplegics who are confined to a wheelchair. The orthotic system takes advantage of the wheelchair yet does not interfere with its functions or wheelchair modification. One of the aims in designing this orthosis is to achieve simplicity by using commercially available components and easily assembled parts.

METHODS:

The proposed control methods take advantage of the available body motion (power) and bioelectric signals of C4-5 quadriplegic patients. The orthotic system includes four bi-directional joints which help the user perform certain daily activities. These joints are (1) Shoulder abduction/adduction, (2) Elbow flexion and extension, (3) Forearm supination and pronation, and (4) Prehension. The generated force and range of motion is limited and is not aimed to mimic the normal arm.

The shoulder/elbow joint: The shoulder joint is abducted horizontally by pulling a cord attached to the contralateral shoulder. The joint is slightly abducted to start with due to the stiffness of the compression spring located on the side of the chair (fig. 1). This spring opposes the gravitational forces acting on the arm. The rotational velocity about the shoulder joint is proportionally related to the rate of contralateral shoulder elevation. This is accomplished with the aid of cables, pulleys, and springs. A torque spring (7.50 in*lb) located respectively at the shoulder joint is needed to help balance the weight of the arm.

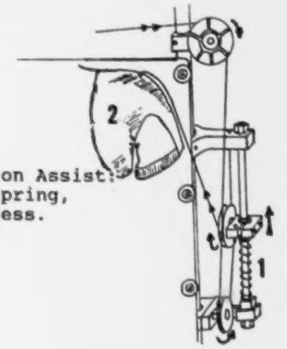

Fig. 1. Shoulder Abduction Assist:
1) Compression Spring,
2) Shoulder Harness.

The pivot of this joint is mounted on the wheelchair and is located behind the center of rotation of the shoulder. The support bar, which guides the arm, changes its angulation with regards to the vertical, through a shaft supported by a bearing mounted in the pivot plate. One of the reasons for using this design was to depart from a distal swivel arm which limits the passage of the wheelchair through standard size doors (fig. 2).

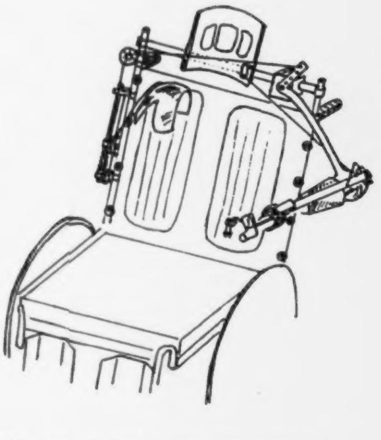

Fig. 2. Hybrid Arm Orthosis.

The elbow is positioned in a cup which is located at the end of the support bar. A forearm support bar is attached laterally to the elbow cup, and is supported by a bearing and torque spring (5.5 in*lb). The torque spring assists the arm in overcoming its own weight. A fixed length push-pull cable runs from the lower arm brace to the back of the wheelchair (2.0 in. from shoulder bearing block). When the shoulder is abducted the cable simultaneously flexes the forearm. Therefore, the amount of abduction of the upper arm proportionally flexes the lower arm.

Pronation and Supination: The function of supination/pronation of the forearm is provided by a spur gear mechanism fitted around the wrist (fig. 3). This gear is driven by a miniature DC motor located at the end of the forearm brace permitting normal unrestricted pronation-supination range at the rate of 30 degrees/second. The motor control system is powered by the wheelchair battery. Control of the motor is provided by air switches. These switches are activated by air bags which are located behind the head, on the head rest. The motor control system is activated by pressing the head against the center bag (12.1mm Hg of pressure). Once the system is active the patient lightly depresses (3.7mm Hg) air bag #2 (left to the center one) to maintain motor activation. Relaxing pressure on the bag halts the motor. A second contact pressure on this bag will reverse the wrist position.

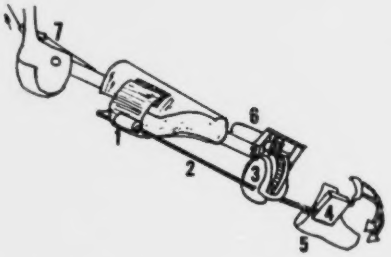

Fig. 3. Lower Arm:
1) Motor (prehension), 2) Flexible shaft, 3) Wrist support, 4) Gearbox, 5) Thumb post, 6) Wrist motor, 7) Elbow flexion cable.

Finger prehension: Finger prehension is provided by powering the metacarpophalangeal (MP) joints of the index and middle fingers. The interphalangeal (IP) joints of these fingers are fixed with a finger splint to provide a three point jaw chuck pinch. The thumb harness fixes the thumb so that it opposes the fingers. Attached to the harness is a gearbox. A flexible shaft is connected to the gearbox and is actuated by a miniature DC motor that is fixed to the medial aspect of the forearm brace. The maximum pinch force at the finger tips is 9 lbs. The motor receives it's control signal from air bag #3 (right of the center one) operating similar to bag #2.

BENEFITS:

(1) The patient will be able to do most of the light tasks a person normally does, such as feeding, handling devices and operating switches.
(2) The patient can accomplish tasks unattended, therefore increasing independency.
(3) The patient will improve his/her self confidence, thus increasing the arsenal of tasks usually attempted.
(4) Mobility of the wheelchair through standard door ways and narrow hallways will be enhanced.

ACKNOWLEDGMENTS:

We thank Jonathan Dietz for sharing his knowledge of electronics with us. The work was supported by the VA RR & D Services.

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A PORTABLE DELTOID AID

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INTRODUCTION

A portable deltoid aid which attaches to a wheelchair has been developed at the Harmarville Rehabilitation Center. Therapists recommend deltoid aids to counterbalance the weight of the arm and to allow vertical movement. Spinal cord injured individuals who need assistance with shoulder, elbow, and forearm movements are the largest population of users. Deltoid aids can be used with either the left or right arm, or with both arms. The aid allows a person to eat independently after his food has been cut up, and to perform vocational tasks which require vertical arm movement assists, such as painting and sanding. The aid can also be used to exercise the arms and build up strength. Commercially available deltoid aids[1] are heavy, cumbersome, free-standing units which wrap around the wheelchair and which are supported on casters. These aids are adequate for use in institutions, but there is a clear need for more portable units which patients could use at home, restaurants, worksites, etc. The device described in this paper is lightweight, portable, and fits to reclining or upright wheelchairs. It is simple for an attendant to take on and off the chair, and separates easily into several pieces.

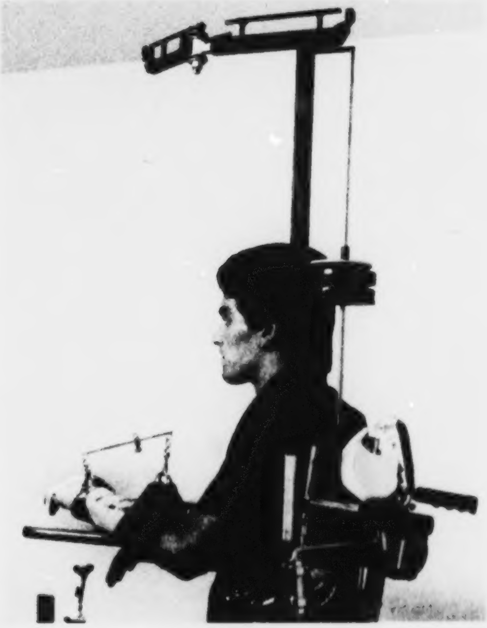

Figure 1.
The portable deltoid aid

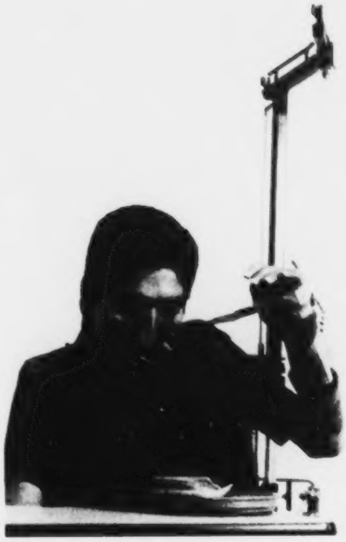

Figure 2.
Arm counterbalanced against gravity
Client eating an apple

METHODS AND MATERIALS

As in commercially available devices, the user's arm rests in a sling supported by a cable attached to counter weights. The cable runs through a system of pulleys attached to a metal frame. In our device, the sling and counterweight system has been incorporated into a lightweight, portable unit which can easily be attached to and detached from a wheelchair. As in some commercially available units, our device contains an elbow swivel joint which allows internal and external arm rotation (figure 3).

The frame of the device consists of 1" and 3/4" square steel tubing (1/8" thickness). Adjustability is provided in several places where the 3/4" tubing can be slid in and out of the 1" tubing. A commercially available reclining wheelchair bracket[2] is modified to hold a 6" long piece of the 1" square tubing. A 9" long piece of 3/4" tubing slides into this piece of 1" tube to provide vertical adjustment of the aid. Two T-handle set screws tighten the tube into place. The other end of the 3/4" tubing is welded to a piece of 1" tube 26" long, which in turn is

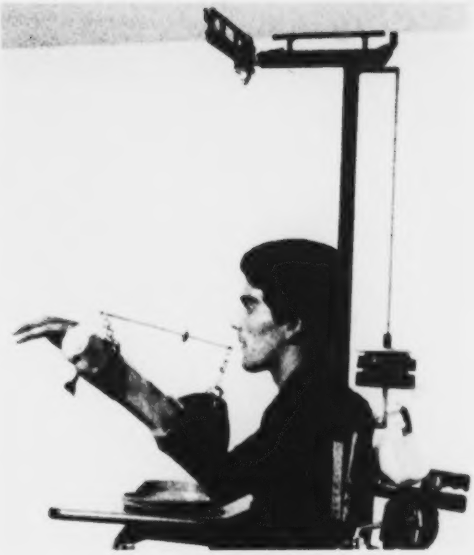

Figure 3.
Arm in external rotation

welded perpendicularly to a piece of 1" tube 8.5" long. A second piece of 3/4" tube 10" long slides in this 8.5" long section of 1" tube to provide horizontal adjustment of the device. A 1.25" long piece of steel pipe is welded perpendicularly to the other end of the 3/4" tubing to provide the housing for the swivel joint. The swivel joint is made by inserting a 9/16" OD bronze sleeve bearing into the 1.25" long piece of steel pipe. A 3/8" bolt rotates freely in the bearing. The distal arm of the device (3/4" tubing 5.5" long, or as measured for the client) is attached to the bolt via a specially fabricated U-bracket welded to the distal arm. Teflon washers separate the pipe shaft from the U-bracket.

Four miniature pulleys[3] guide stainless steel wire rope[4] through the aid. (Commercially available deltoid aids use 1/16" thick fiber cable which breaks easily). Single pulleys rest at each end of the horizontal tubing system at the top of the device. Two pulleys lie side by side with their bores oriented vertically, atop the swivel joint; the cable runs between these pulleys and is guided by them as the distal arm of the device pivots. The cable runs through steel tubing (1/4" ID) welded on top of the horizontal tubing system.

The user's arm rests in a simple leather sling which is attached to a slide bar. The cable can be moved to any portion of the slide bar via a set screw. This allows various forearm angles to be attained. To obtain the optimum amount of counterweight, the user can choose between any combination of two 0.25 lb. weights, one 1 lb. weight, two 1.25 lb. weights and one 2 lb. weight. A guide and support for the weights is made of 0.063" thick aluminum plate (4" in diameter) welded to 1/2" OD, 0.065" thick aluminum tube (3.5" long piece). The weights are slotted to fit around the aluminum tube and the tube slides up and down a 3/8" shaft welded to the main frame.

The deltoid aid is dismantled by removing the weights, unscrewing the two set screws with T-handles which hold the 3/4" tubing in place at the base of the device, and then removing the device from the wheelchair. Further dismantling can easily be accomplished, but is not recommended in daily use.

The device is painted black except for the moving parts, which are chrome painted. We tried to keep the design sleek and streamlined to promote user acceptance.

DISCUSSION

The device pictured has been in use for the last five months. The patient uses it at home on a daily basis and is pleased with its performance. He has gained function in his upper extremities, and feels that the deltoid aid is at least partially responsible for his gains. Another of these devices is currently being fabricated for a second young spinal cord injured client.

Motivation and family support are very important to the acceptance of this device. Although it is sometimes easier for an attendant or family member to do a task for an individual, the use of the portable deltoid aid will provide increased independence and self-esteem and will help to maintain and develop arm strength. Its portablility will promote increased use of the device in a home or work setting.

FOOTNOTES

1. Two distributors of deltoid aids are:
   MED (Medical Equipment Distributors, Inc.)
   MED Help Arm, #OC-1263
   and
   CLEO Living Aids
   Deltoid Aid, #53-1008
2. Fred Sammons, Inc.
   Reclining wheelchair bracket, #BK-7126
3. McMaster Carr Supply Company
   zinc plated steel pulleys with ball bearings,
   3/64" cable diameter, #3434T21
4. McMaster Carr Supply Company
   3/64" diameter type 302 stainless wire rope,
   7x7 strand core, 270 lb. breaking strength, #3434T21

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A NEW MYOELECTRIC ORTHOSIS DESIGN FOR SCI PATIENTS

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ABSTRACT:

A development of a new proportional myoelectric prehension orthosis for C5-6 Patients is reported in this paper. The device is independently donned and controlled and it offers compatability with other daily activities. Other unique features include a pinch force of up to 9.0 lbs. which is monitored by a sensory display.

INTRODUCTION:

The challenge faced by designers of powered upper extremity orthoses for paralyzed patients has changed little since the start of the century (1-5). Researchers are still trying to develop devices that are comfortable, easy to control, and reliable. Although orthoses currently on the market provide prehension for C5-6 level patients, they have yet to be widely accepted (6-12). Reasons for their rejection include: 1) poor recommendation and fitting, 2) poor performance of the devices, 3) the need for on-going assistance in donning and doffing, 4) technical failure, 5) poor integration of the device in performance of other daily activities, 6) poor cosmesis, 7) excessive cognitive requirements by the control method. Presently, surgical procedures provide little if any relief to quadriplegics who lack normal hand function. Therefore new external devices and effective rehabilitation must be developed if the independence of the growing spinal cord injury population is to be improved.

OBJECTIVES:

The objective of this study was to develop a powered orthosis for the C5-6 quadriplegic that will restore prehension to the fingers. Our goal was to design a device that would be used in both the early stages of rehabilitation and also following recovery. We also aim to incorporate pinch force feedback via a visual display.

METHOD:

The orthosis consists of two parts; hand and forearm that are interconnected by a flexible shaft. A hook at the end of the forearm band is used to pull the flexible band hand harness over the arm and hand. The fingers are attached to the guide with another hook and velcro combination. The linkage kinematics are adjusted for each patient. Prehension is produced by the device through a three point jaw-chuck mechanism that is used in the flexor hinge hand splints. The hand portion of the orthosis also includes a gear box and thumb post that opposes the index and middle finger. A spur-worm gear combination is mated to the flexible shaft which is connected to a miniature DC motor mounted on the forearm band (fig. 1).

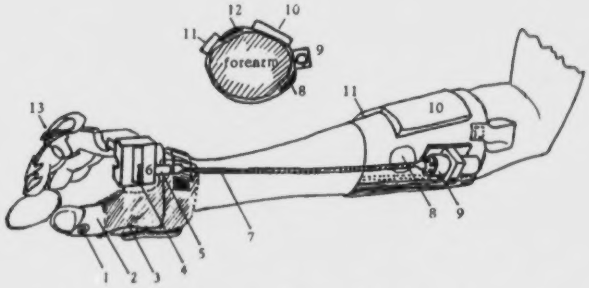

Fig. 1. Prehension Orthosis
1) Load cell, 2) Thumb harness, 3) Wheelchair glove, 4) Gear housing, 5) Gear-shaft connection, 6) LCD display, 7) Flexible shaft, 8) Wrist flexors electrode, 9) Motor, 10) Circuit, 11) Battery, 12) Wrist extensor electrode, 13) Three point jaw-chuck brace.

The motor is controlled by signals from electromyography (EMG) dry skin electrode/s which are located above the wrist extensor and wrist flexors (when available). A one electrode ("two state") control method is used if the wrist flexors are non-existent. This control method has two states, the active signal closes the hand while the absence of a signal opens it. With the two electrodes ("three state") control method each electrode is responsible for either opening or closing the fingers.

The grip strength generated is proportional to the level of the EMG signal. When a signal is not generated the device is turned off. The user has the option of turning off the device when performing conflicting activities or in cases of loss of neuromuscular function. A miniature LCD display is mounted on the gear cover (fig. 1). This provides a convenient visual feedback of the generated pinch force. The display is a nearly linear representation of the output force, since the current draw of the controller is proportional to the force. However, a more linear signal source can be supplied by a miniature load cell located beneath the thumb at additional cost.

A single rechargeable 6 volt battery supplies the energy for the electronics, the motor and the electrodes. These components are conveniently mounted on the forearm band. The total weight of the device is 300 grams; the hand portion weighs 100 grams and the forearm band weighs 200 grams. Power to the motor is regulated by an automatic current limit controller which limits the maximum pinch force to 9.0 lbs. The time required to cover a range of 3.0 inches (motion form open to close is 10.0 seconds.

BENEFITS:

One patient using the "three state" controller has been tested so far. He has derived the following benefits.

1) The prehension orthosis has given the patient increased independence. This is accomplished by restoring some voluntary hand functions. The patient also does not require any assistance in operating the device.

2) The orthosis has improved the self-confidence of the user and encourages him to try new activities which would otherwise require assistance.

3) The orthosis does not interfere with the patient's daily activities.

ENHANCEMENTS:

1) Manufacture standard sizes to fit various users such as high C5 and C6 patients, for whom the location of electrodes must vary.

2) Build adaptive versions for use in occupational therapy in treating patients with tendon transfer, peripheral nerve injury and other neuromuscular injuries requiring extended therapy with precise torque and range of motion.

3) Improve response rate of finger closure.

4) Improve the electrotactile feedback methods to be used as alternative or additional sensory display. An alternate audio-tactile method of feedback is under development which will be applied through a piezo sensor skin electrode. The electrode uses a vibrating low frequency tone to control grip strength.

5) Explore avenues of alternative control methods such as EMG or switch controlled transcutaneous stimulation of the muscles responsible for prehension.

ACKNOWLEDGEMENTS:

The consultantship of Steve Greelish is greatly appreciated. This work was supported by the VA RR&D Service.

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GAITALERT: A BIOFEEDBACK DEVICE USED FOR MONITORING HEEL POSITION DURING GAIT AND STANDING

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INTRODUCTION

Audio-biofeedback can provide an alternate sensory system to be used during gait by providing the subject with information about the quality of this gait. It has been shown that audio-biofeedback can effectively improve other performances of subjects with cerebral palsy [1]. This paper discusses the design, implementation, and application of such an audio-biofeedback device called Gaitalert.

PROBLEM

T.D. is a five year old girl who is bright, active and also has mild cerebral palsy. She walks with a typical diplegic gait, i.e. equinus (tip toe) walking with femoral anteversion (medial rotation at her hips). She is able to heel-strike, but only does this with concentration and verbal reminders from caregivers. This alone, however, has not been consistent enough to help reinforce this more desirable gait. An audio-biofeedback device for monitoring the position of a single heel was implemented in the United Kingdom [2]. Unfortunately, a review of this device revealed that it could not be used satisfactorily in bilateral applications. Furthermore, using two of these devices simultaneously for heel position was felt to produce feedback which was too confusing to be effective.

SOLUTION

Gaitalert is a portable audio-biofeedback device which monitors the position of both heels in a standing posture as well as during walking. The device presents the user with a power switch, two jacks for foot switches and a time delay adjustment. It is battery powered and small enough (110mm x 70mm x 35mm) to be worn on a belt.

The two foot switches are flat, round pads - about 3.5 cm in diameter. The foot switches were placed underneath the subject's shoe inserts (UCBL foot orthosis) at the heels. For patients without inserts we plan to use these foot switches built into foam inserts. The cables were routed inside each pantleg to the unit at the waist.

The unit is quite simple to operate. The Gaitalert is basically a variable delay alarm which can be reset by specific foot switch activations. While a correct standing posture or gait is maintained, the device will remain silent, assuming the time delay has been appropriately adjusted. When an error is encountered, the alarm is delayed for a time preset by the time delay control. Unless corrected within this time, the alarm will sound until the condition is corrected.

A correct standing posture is recognized as one in which both heels are bearing weight. If one or both heels are raised an error status is initiated. Both heels must be firmly planted again, within the time delay, to prevent the alarm sounding.

A correct gait, is recognized by the device as one in which each heel alternately makes contact with the ground. The time delay control is set to sound the alarm after a time slightly longer than the slowest heel to heel time. As each heel leaves the ground an error pending status is asserted and can only be reset by the same heel re-contacting the walking surface. Thus, when a heel misses a step the alarm is sounded and corrected only by that heel making contact again.

It is assumed that every gait sequence will start and end with a standing position. If the user were, for example, to sit with their feet off the ground, they would need to turn the device off. Also, it is assumed that the user can understand the cause of the alarm and react appropriately.

The Gaitalert may also be used to monitor a single foot switch by using only one input and adjusting the time delay accordingly.

FINDINGS

With the Gaitalert connected and adjusted for T.D.'s gait, she immediately showed an improved gait, although she walked a little slower than usual. The monitor reminded her to walk with heel strike and she had no difficulty in understanding the biofeedback concept as implemented in Gaitalert. By putting her heels down she also automatically reduced the tendency for femoral anteversion.

It is hoped that reinforcement of heel strike and pressure through her heels will strengthen this movement pattern and over time will diminish her previous tendency to walk on her toes.

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FLEXIBLE-JOINT PIPE: AN ORTHOTIC/PROSTHETIC TOOL

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ABSTRACT

The Flexible-Joint Pipe is an orthotic/prosthetic tool that prevents breakage of positive plaster molds of extremities. Possessing a flexible (bendable) joint, the tool can curve at the bends of the mold caused by anatomical joints, such as an ankle or wrist, thereby reinforcing the full length of the positive mold. The device is very simple to use and is durable enough to be used and reused.

INTRODUCTION

In the field of orthotics and prosthetics, casts or molds of extremities are formed in a somewhat standard routine. First, the client's extremity is wrapped with casting plaster, which is removed when hard. This cast, being the negative mold, is then filled with plaster of paris to produce a positive mold. The positive mold, used throughout the fabrication process, must be durable.

Currently, a straight, nonflexible pipe (standard plumbing pipe, generally) is placed into the plaster of paris prior to hardening as reinforcement. This pipe is used to clamp and hold the positive mold during both mold modification and fabrication.

Because the pipe is nonflexible, it cannot curve at the bends of the mold. The sudden termination in reinforcement causes a stress concentrator in an already fragile plaster mold. Consequently, the terminal portion of the mold frequently breaks off, resulting in compromised company efficiency and service quality (if the mold cannot be repaired, the patient must return for recasting).

METHODS

In order to prevent the breakage of molds, an improved pipe has been developed. This pipe incorporates a flexible joint to allow for bending and shaping. Therefore, it can be contoured to match the bends of the mold. This results in a full-length reinforcement of the positive mold, which eliminates breakage. The flexible joint is protected with a plastic sheath to maximize durability.

RESULTS

Several prototypes have been developed and tested within the University of Virginia's Division of Prosthetics and Orthotics. Both full length (KAFO) and half length (AFO) models exist. The results have been dramatic. Essentially, mold breakage is no longer a problem. Even intentional damage inflicted to the mold has not caused shattering; the flexible joint maintains its reinforcement. The tool is also proving to be durable, with use and reuse not affecting it adversely.

CONCLUSIONS

Due to the success with the prototypes, the University of Virginia is currently studying patent and commercialization feasibility. It is hoped that a prosthetic/orthotic supplier will procure the rights to the tool, making it available to all practitioners.

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“SPECIAL INTEREST GROUP”. 5

Quantitative Assessment
Évaluation fonctionnelle

ICAART 88 - MONTREAL

NUMBERS AND NONNUMBERS: A SOURCE OF ERROR IN REHABILITATION DECISION MAKING

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INTRODUCTION

Assessing the effectiveness of new equipment, techniques, or treatments is a necessary but difficult task. One problem is that frequently measures must be taken along many dimensions. Some dimensions are more easily measured (e.g. strength, durability) but we also need to measure other variables, such as functional advantages to the patient, that are more problematic to quantify. As a consequence, assessment scales reflecting the utility of techniques or products and their impact on patients are in demand. Equipment and procedures must be compared for efficacy and functional outcome. Clients are complex, often with skills, capabilities, and plans that would each require a different solution, when only one device or procedure is possible. Of course, greater confidence can be placed in a decision based on measures that are objective as opposed to subjective. However, not all objective measures provide the same basis for decision making; one must also consider the properties of the measurement scale itself. The present paper will discuss some prevalent misuses of scale information in decision making as it applies to rehabilitation.

TWO COMMON TYPES OF MEASURES

Two classes of measurement are of interest. First, **ratio** type scales involve the comparison along dimensional quantities for which we have natural science measurement scales (3) and engineering units, such as mass, length, force, etc. Ratio measures have a zero point and an equal interval scale. Usually, it is not the dimensions for which we have ratio scales that are troublesome in decision making; we can easily measure mass and determine that one wheelchair is heavier and how much. Second, **ordinal** type scales give a ranking ("order") of items, but not magnitude of difference. These scales can be subjective, as when you determine that one chair is less comfortable than another, or objective, as with common "functional independence" measurement scales that "behaviorally anchor" their ratings.

Ordinal scales have become widely used because they offer a quick, easy, inexpensive means of quantifying complex information along many dimensions with an illusion of mathematical precision. In engineering, such scales have been used to rate alternative designs. In medical settings, such as rehabilitation facilities, there is a growing trend to apply such scales to the issue of functional outcomes (1,2), and recent publications in the physical medicine literature endorse the use of ordinal scale-derived data for clinical decision making.

AN ORDINAL SCALE

Consider the following ordinal system (with two subscales) for assessing a new wheelchair design:

Item 1: Degree of **independent use** by patient:
None Minimal Moderate Complete
0 1 2 3 4 5 6 7 8 9 10

Item 2: Patient's **approval** of new chair:
None Minimal Moderate Complete
0 1 2 3 4 5 6 7 8 9 10

Although the symbols used for ordinal scale analyses appear to be real numbers, they are not, because our assignment of every number to its scale position is arbitrary; there is no equality of distance between the items. As "nonnumbers", they are at best symbols of "greater than" and "less than" quantities. With real quantities, such as three different sized sacks of flour, we could put the two smallest unknown quantities together and say that the result is bigger than either of the two sacks which we combined. However, we still don't know if our combined quantity is larger or smaller than our "biggest" sack of flour. (Such a statement can be made with a ratio type measure such as volume or mass.) Also, because of the relative nature of ordinal scale increments, we cannot say that combining two "quantities" will result in an amount that is smaller or larger than the next increment on the scale. One plus four does not necessarily equal five; all we know is that it is greater than four. Similarly, four plus five may not equal nine. It is simply greater than four.

How about cost effectiveness? Consider evaluating two devices with Item 1 (above). Device "A" on which a patient moved from 2 to 4, or device "B" on which a movement from 4 to 5 took place? Even if equal costs per day for each device is assumed, and if the number of days is known, cost effectiveness cannot be determined because the distance between 2 and 4 is not known relative to the distance from 4 to 5. It is logically fraudulent to subtract the rating admission from the rating at discharge and divide the remainder in order to derive a change score. All that can be derived is an unquantified, nonsense nonnumber that has different unknown meanings for different patients.

The above problems become compounded further when one yields to the admittedly inviting temptation to add the item scores for an individual to calculate a total for that patient for the various items on the scale. The fundamental problem with such a calculation is that its meaning cannot be interpreted, although this may not be immediately apparent. First, when one totals the ordinal scale item nonnumbers, all that can be supported is that the total is greater (although to what degree is unknowable) than any of the individual item scores that were added. In addition, once having calculated a total of the item scores, it is not possible to know whether that total is composed of high scores on some items and low scores on others, consistently moderate scores on all items, or some combination thereof. Thus, nonnumber totals do not have the same meaning for one individual as for another, and trying to extract meaning from such total scores creates confusion rather than provides meaningful information. Further, with reflection it is obvious that to reach a total score across items for a given individual is to add information across content domains (the proverbial addition of apples and oranges). To total the items across domains eliminates the possibility of considering the resultant data to be even ordinal level. As can be seen from our "wheelchair effectiveness scale" as given above, both items go in the same direction: e.g. 'complete' =10. However, while we have discussed the difficulty of interpreting information within a single content domain, consider the difficulty of interpreting aggregates of data across content domains. We have already concluded that we know only that 'minimal' is smaller than 'moderate' but not how much smaller. Now consider that we also do not know if the quantity 'minimal' in independence is bigger or smaller than 'moderate' in patient's approval. Thus, adding a '4' on Independence to a '6' on Approval and calculating an average of '5' has no logical meaning.

While these problems are clearly part of most 'homemade' scales routinely created on an ad hoc basis, one may be tempted to assume that nationally used scales that have been through a standardization process are somehow statistically made "better". While it is true that some ordinal level scale are superior to others (a topic too large for the present space), and that careful consideration and a large data base certainly help in decision-making, it is also true that ordinal scales are not made into ratio-level measures by statistical wizardry. Furthermore, simply because results are statistically significant (and have been published) assures neither that a meaningful interpretation is possible nor that the results apply to your patient.

CONCLUSION

The proliferation of such ordinal rating scales and their increasingly common use in rehabilitation settings lends tacit support to the sensibility of their use regardless of the errors in decision making which they are likely to promote. What is in common usage becomes accepted as the norm and, with the passage of time and the continuation of the usage, becomes less and less likely to be questioned. "This is the way it's done" becomes an easy response to those who may express skepticism. However, sometimes there are alternatives; see (3) for guidelines on the ratio-quality measurement of behavior, and some examples of such measures can be found in the rehabilitation literature (4,5). We can devote more to development of ratio-type measuerment and decision-making tools. Finally, we can simply examine the assumptions underlying the scales we commonly use, and resist undue inferences; adding, subtracting, multiplying and dividing these 'nonnumbers' when we make decisions can lead us to deceiving ourselves.

ACKNOWLEDGEMENTS

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FUNCTIONAL ASSESSMENT: DEVELOPMENT OF A PORTABLE SYSTEM FOR MOTOR ABILITY EVALUATION IN TRADITIONAL AND THERAPEUTIC RECREATION SETTINGS

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ABSTRACT

Instrumentation and methods were designed to test rudimentary motor abilities in clinical and field settings. Subjects in therapeutic activity programs were tested before and after a one hour period and retested six weeks later. Subjects with a wide ability range could be tested without disrupting therapy sessions. Results corroborated with past research (Winnick & Short (3); Fox, Lawlor & Luttges (2)).

INTRODUCTION

Despite recent technological gains tracing the neural and muscular components of motor output, and calls for evaluation tools by practitioners (Connolly (1)), rehabilitation programs have not received adequate funds to develop assessment methods. Current motor evaluations use subjective methods or are costly, nonportable means. Thus, many therapeutic programs do not provide objective baseline and subsequent assessments allowing prescriptive therapy and documented progress.

In this study objective quantification tools to assess motor ability of disabled persons in therapeutic recreation and clinic based therapy programs were developed. Rudimentary motor abilities inherent to learned skills were chosen for testing. In light of the current prevalent use of subjective evaluations, such components were also included.

The following concerns guided the development of the methodology. 1. Design objective, quantitative metrics for dynamic posture, strength and coordination. 2. Develop methods usable for a wide ability range. 3. Establish unobtrusive, noninvasive and easy to administer tests. 4. The apparatus should be portable, allow for reproducible data, allow for repeat assessments and offer within as well as across intervention program comparisons.

A therapeutic horseback riding and handicap swim program were invited to participate in this study for the following reasons: both programs are designed and delivered by physical therapists and certified instructors; they have consistently used subjective evaluations to increase program efficacy; program directors have expressed interest in obtaining objective assessments; these programs stress safety, enjoyment, sense of achievement and physical progress and all participants have parent and physician clearance to participate.

Therapeutic riding has been suggested to improve sitting balance and coordination and reduce spasticity, whereas, improvements seen during therapeutic swim programs include better strength and endurance. Indirect benefits of both programs include increased social skills and self confidence. The nature of swim and riding programs accommodates a wide range of rehabilitative needs.

METHODS

Subjects. Group 1 consisted of volunteer Ss, 6 males and 5 females, 10 to 50 years of age, participating at the Colorado Therapeutic Riding Center Inc. (CTRC) at Schooley's stables in Boulder, Colorado. Handicaps included cerebral palsy, learning disabilities, hemiplegia, mild to moderate mental retardation and some vision and hearing defecits.

Group 2 consisted of volunteer Ss, 7 males and 5 females, 7 to 50 years old, participating in the Expand swim program at North Boulder Recreation Center, Boulder, Colorado. Handicaps included cerebral palsy, multiple sclerosis, learning disorders, mild to moderate mental retardation and some hearing and vision disorders.

Each subject participated in a 15 minute test session before and one session after the therapeutic activity. Six weeks later the testing protocol was repeated. All testing was done at therapy locations.

APPARATUS

The apparatus was designed and built in the Department of Aerospace Engineering Sciences at the University of Colorado, Boulder. It consists of a symmetrical balance beam supported by a bearing affixed to a triangular shaped base. Behind the bearing, the shaft of the balance beam is clamped to the slider of a high quality wire-wound potentiometer. All movements of the beam are translated into variations of electrical resistance. The apparatus includes a feedback unit which generates visual and auditory responses to Ss performances.

Detachable hand dynamometers can be affixed to the apparatus allowing grip and other strength testing. Force mechanically moves a pointer to the appropriate kilogram reading. Additional equipment included a 12 inch jointed goniometer to measure dynamic posture.

Tasks: Dynamic Posture. Tests were designed to assess upper body range of motion. Ss sat as straight as possible then leaned as far forward, back, left and right. The angle of body closure or extension was measured for each lean.

Strength in legs/feet. The apparatus was placed on the floor and one leg at a time was set on the beam. Ss pushed maximally and released. Two trials were given for each foot.

Strength in arms/hands. The apparatus was placed on a table and one arm at a time was set on the beam. Ss pushed maximally and released. Two trials were given for each arm.

Grip strength. A hand dynamometer was fitted to each subject. Ss squeezed the dynamometer maximally then relaxed. Two trials were done for each hand.

Coordination of hands/arms. Both hands were placed on the beam. On two trials Ss moved the beam as quickly as possible from a tilted to a balanced position and held it there for the remainder of a 10 second trial.

Coordination of feet/legs. Both feet were set on the beam. On two trials Ss moved the beam as quickly as possible from a tilted to a balanced position and held it there for 10 seconds.

Subjective evaluations. Ss were evaluated by their instructors using a questionnaire. Changes over six weeks for balance, coordination, posture trunk range of motion, arm and leg strength, attitude, self confidence and self respect were noted.

Data Analysis. In this study personal criteria were used. The best score obtained on a task was termed 100% for the subject. All other scores were a percent of the peak.

Analyses of variance (ANOVA) were completed for each assessment category. Correlational analyses were run among the several tests in each category. A sign test was used to determine significant differences on subjective data. In this study an alpha level of 0.05 was accepted as significant.

RESULTS

Correlations. Positive, significant correlations were seen among the 5 posture indices, the 3 strength and the 2 coordination measures. Coefficients ranged from +.607 to +.982

Analysis of Variance. Results for week 1 dynamic posture indicate improvements after activity, although not significant, for all Ss, with riders improving the most. Trends were repeated at week 6. Results for week 1 strength indicate that swimmers improved significantly more than riders (F (1,22) = 4.88 p .05). This trend was repeated at week 6 although not significantly. Results for week 1 coordination show that riders improved more after activity than did swimmers. Data did not quite reach significance. Week 6 data were similar with riders improving significantly more (F (1,22) = 4.53, p .05).

Subjective evaluations. Instructors rated Ss as having significantly more improvements than decrements on posture, strength and coordination over the six week period.

SUMMARY AND CONCLUSIONS

In this study methods to objectively assess motor ability of individuals with a wide range of disabilities, were developed. Tests were unobtrusive, easy to administer and equipment was portable. Results indicate that after a one hour therapeutic riding session Ss showed improved dynamic posture and coordination but showed decreases in strength. After 6 weeks strength improved also. Swimmers showed improved posture and strength but no change in coordination. Such tests may allow participants and therapists desparately needed assessments for progress checks.

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A SYSTEM FOR MONITORING TRUNK CONTROL AND HEAD POSITION DURING A REACHING TASK FOR PERSONS WITH HEAD TRAUMA

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ABSTRACT

In the early weeks following a brain injury, many patients are seated in wheelchairs for prolonged periods of time. Currently there are few tools available to quantitatively evaluate the function of the seated patient. The need for the evaluation of the body symmetry and the postural control of head trauma and CVA patients in the seated position has lead to the development of a system which will monitor center of pressure and head position during the performance of a reaching task. The system provides the means to quantitatively identify if any differences in body symmetry, alignment and postural control are present between head trauma, CVA patients and able-bodied subjects.

INTRODUCTION

Head trauma and CVA patients are known to experience a loss of muscle tone in the weeks and months after brain injuries. This state is followed by the development of patterns of increased muscle tone which alter their body alignment and symmetry. The degree of malalignment is thought to be an important clinical index of motor dysfunction. Postural sway, especially its amplitude and smoothness is believed to be related to disturbances in motor control. The identification of characteristic body symmetry and postural sway patterns would have a great impact on the development of therapeutic strategies for the treatment of these injuries. Since head trauma and CVA patients are generally wheelchair-bound in the first stages of their recovery, it is necessary to perform any type of functional evaluation in a seated position.

INSTRUMENTATION

One parameter of the reaching task we examined is the motion of the position of the center of pressure. The projection of the center of gravity of the subject in the plane of the seat of the wheelchair (center of pressure) is monitored by a four-point support system which consists of four force transducers placed under the wheels of the wheelchair. The force transducers produce an output voltage directly proportional to the applied force. The center of pressure is calculated by taking moments about the center of the wheelchair/subject system since this system is in static equilibrium with respect to the floor. The forces detected by the transducers are used to calculate the coordinates of the center of pressure using a combination of the hardware and software developed for this study. The transducers consist of strain gauges attached to a central plate supported by two cantilever beams. This design for the transducers gives an output which is independent of the wheelchair used and constant over the surface of the plate (3). The voltage signals from the four transducers are sent through a Scientific Solutions A/D converter with 12 bit resolution interfaced with a personal computer to be digitized.

Labtech Notebook, a commercially available software package, is used to perform the data acquisition. The sampling frequency and duration of the sampling period are controlled by this package. The software samples data from the transducers at a rate of 20 Hz per channel. The files of the coordinates of the center of pressure are later used to statistically analyze the trajectory of the center of pressure and to produce a hard copy of the graphs for visualization.

The second parameter of interest is the position of the head. The head position is monitored by the 3Space Isotrak, (Polhemus Navigation). The monitor contains an electromagnetic source and sensor which are used to track the head position and orientation. The position of the sensor, and therefore the head, is provided by the monitor with six degrees of freedom: three for translational movements and three for rotation. The data are input to the personal computer through an RS232 serial interface at an effective rate of 5 Hz per channel using the data acquisition software described above. An animated replay of the reaching task, much like the stick figures used in gait analysis, is provided by the computer graphics program of this system.

CLINICAL EVALUATION

This study consisted of an analysis of thirteen subjects: seven normal subjects, three head injured patients, and three CVA patients. Each subject executed a forward and backward reaching task for 60 seconds while seated in a wheelchair. A target was placed in front of the subject on and one half arm lengths of maximum extension away from the achromium, measured while the subject was seated in an upright position in the wheelchair. With one arm extended, the subject reached across his body toward and away from the target at a comfortable pace. The reaching task was then repeated for the other arm.

Once the data were collected and stored, a BASIC program dissected the graphs of the X and Y coordinates of the center of pressure vs. time into four components:

1. Forward reaching regions, where the subject moves toward the target;
2. Plateau regions of extension, where tracking for the target occurs;
3. Backward reaching regions, where the subject moves back toward the upright position;
4. Plateau regions of relaxation, where the subject regains stability in the upright position.

DISCUSSION

Preliminary studies with this monitoring system clearly show that able-bodied subject had greater stability during the reaching task than the head injured patient group. Large standard deviations indicating both intra and inter subject variability were obtained. The design of these preliminary studies do not account for factors such as dependence of sway on velocity, or learning effects due to the repetitive nature of the task. Further careful design of tasks may help to describe trunk and head control for these subjects for predicted and unpredicted stimuli. This in turn may help to provide greater discrimination of injury related motor control deficit in the sitting position.

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DEVELOPMENT OF AN ELASTIC HUMAN-SEAT INTERFACE PRESSURE SENSING SYSTEM

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INTRODUCTION

A major factor in the perception of comfort when sitting on an elastic cushion is the distribution of pressure between the human and the elastic medium. Pressure sores arising from high concentration of pressure at the human-seat interface pose severe physiological problem for patients with insensitive skin and physical disabilities [1]. Seating comfort in a dynamic environment, such as for driver of off-road vehicles, is strongly related to the pressure distribution at the human-seat interface. Although significant progress has been made in reducing the magnitude of injurious vibrations transmitted to the driver via effective primary and secondary suspensions, the design of cushions to redistribute the forces at the human-seat interface has drawn only minimal research efforts [2].

The design of a cushion requires an objective knowledge of human-seat pressure distribution characteristics of the cushion. A number of measuring systems have been developed to achieve this. Sensors, such as rubber butterfly valves, manometers, bed of nails and springs, sprung flat boards, strain gages, silicon diaphragms, etc. have been used in conjunction with multi-channel data acquisition systems to acquire distribution of pressure at the human-seat interface [3,4]. Nearly all of these systems have severe limitations in view of the flexibility of the interface. These sensors either are applicable to hard surfaces or alter the elastic properties of the interface considerably. In this paper, a pressure measuring system,comprising of 0.25 mm thick foil resistors, multichannel data conditioner and acquisition, is proposed for measurement of static as well as dynamic pressure distribution at the human-seat interface.

PRESSURE MEASUREMENT ON CONTOURED ELASTIC SURFACES

Measurement of pressure distribution at a human-seat interface requires a comprehensive grid of ultra thin deformable sensors, such that the elastic properties of the interface remain almost unaltered during measurements. In view of the large number of sensors required, the cost of sensors is also an important factor. Majority of the pressure sensors developed are not thin enough to be used for a flexible interface and moreover the cost of large number of such sensors may be excessive. A qualitative measurement of pressure distribution on soft surfaces has been obtained using copy carbon paper [5]. Recently, 1 mm thick foil capacitors have been used to acquire human-seat interface pressure distribution [6].

Sensors and Static Calibration:

The basic sensing element comprises of ultra thin and deformable force sensing resistor and a film of foil conductors. The force sensing resistor consists of a polymer sheet with a layer of flexible sensing film. The foil conductor film is a mylar sheet with interdigitated pattern of open ended conductors. The infinite resistance of open ended conductors is shunted by placing the force sensing resistor against the foil film. The resistance due to the force sensing resistor changes with changes in the load. Thus the shunt resistance of the assembly is related to the force applied to the surface. The sensing assembly, comprising of two polymer sheets, is 0.25 mm thick and approximately 9.75 mm diameter and quite inexpensive.

The pressure sensors are calibrated in the laboratory to determine the resistance-force relationship, precision and repeatability, using a pneumatic actuator. The force-resistance relationship of the sensor assembly is observed to be repeatable, however quite nonlinear, as shown in Fig. 1. Each sensor has a conditioning differential circuit comprising of constant current supply (0.24 mA) at 1.5 V, which is configured to interpret the pressure/resistance variations in terms of voltage variation. The static calibration curve is thus obtained to provide voltage vs pressure characteristics of the sensing assembly (Fig. 2). A numerical curve fit algorithm is employed to describe the static equilibrium curve via a cubic polynomial.

Measurement and Acquisition:
A feasibility study on measurement of pressure distribution over an elastic human-seat interface is carried out by mounting eight sensors in a grid fashion. The voltage output of each sensor is digitized using an A/D converter. A multi-channel data acquisition card is assembled to acquire the digital voltage data on the IBM-PC. The instantaneous voltage output is converted to the instantaneous interface pressure using the cubic calibration equation.

CONCLUSIONS

Assessment of seating in a static as well as dynamic environment requires objective measurement of pressure distribution at the human-seat interface. Pressure measurement on such elastic surfaces requires ultra thin and deformable sensors, such that the elastic properties of the interface remain unaltered. Foil resistors, 0.25 mm thick, have proven to be feasible sensors.

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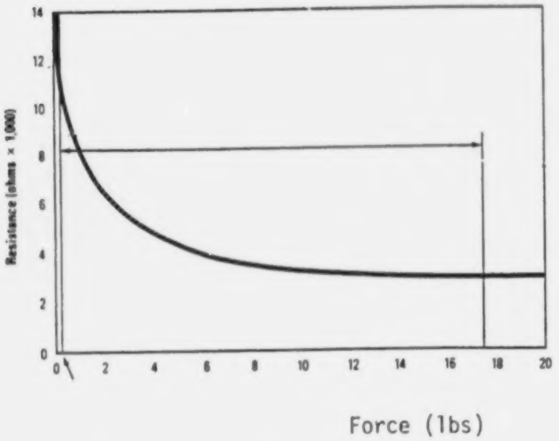

FIGURE 1

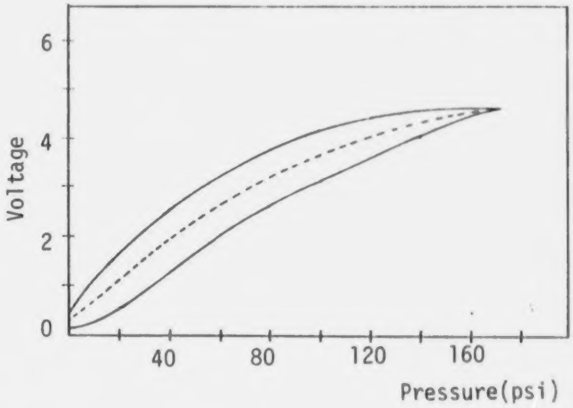

FIGURE 2

A MICROPROCESSOR-BASED WHEELCHAIR DATA LOGGING SYSTEM

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University of Virginia Rehabilitation Engineering Center

INTODUCTION

A knowledge of the stresses experienced by wheelchairs is necessary in the ongoing effort to improve chair design. To date, design parameters have been obtained primarily from laboratory tests. Aside from user surveys, very little information exists concerning wheelchair activity experienced in normal daily use. A means of systematically recording data on a wheelchair's activity can prove useful to future rehabilitation studies (1).

A portable electronic data logger for automatically recording various parameters of wheelchair activity has been developed in conjunction with the University of Virginia Rehabilitation Engineering Center. The microprocessor-based logger records number of uses, time in use, time in motion, distance traveled, velocity, acceleration, and tilt while attached to a test wheelchair for about a week. Upon completion of a test, the logger transfers its data to an IBM-PC host computer in RS-232-C format. Host programs have been developed to conveniently receive, store, and display the logged data for future analysis. Finally, operation of the prototype system has been successfully demonstrated in the laboratory and in limited actual tests with disabled wheelchair users (1).

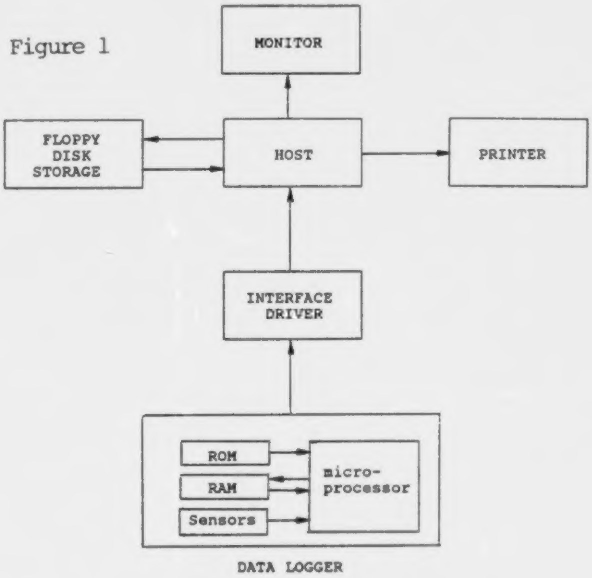
SYSTEM OVERVIEW

The entire wheelchair logging system can be divided into three basic components: the portable data logger, host computer, and the serial interface providing communication between the logger and host. A block diagram of the complete system is given in Fig. 1 (1).

The data logger

The data logger consists of the microprocessor, associated memory, and sensors. The prototype uses the Texas Instruments SE70CP162 developmental microprocessor containing all of the required logger memory on the processor chip itself. This includes 256 bytes of internal RAM for data storage and processor work space in addition to 4K bytes of program memory in the form of a 70C128 EPROM plugged into a piggyback socket on top of the microprocessor chip. This feature allows for easy program modification by simply reburning the piggyback EPROM. The final design for mass production may employ this prototype processor, or if there are no foreseeable modifications in the program code, the developmental chip may be replaced with the TMS 70C42 version containing 4K bytes of factory-maskable ROM (2).

Figure 1



The logger uses a touch sensitive seat sensor located on the chair to determine the number of uses, that is how often the user sits down, and the total time seated. Time in motion and distance traveled are measured by monitoring a magnetic sensor, mounted to the chair's frame and wheel. By measuring the ellapsed time between revolutions, the logger calculates velocity which is tabulated as a distribution over forty-eight increments in processor memory. The prototype records forward acceleration as a distribution over five magnitudes, and is measured using a pendulum accelerometer designed by the author. Furthermore, vertical acceleration is recorded using a bilevel shock sensor employing two mercury switches oriented to respond to two different levels of shock. Finally, the prototype employs a mercury tilt switch and filter to register levels of inclination on the order of thirty degrees sustained for at least 1/2 second (1).

The portable logger is conveniently housed in a 7 1/2 x 4 1/3 x 2 1/5" durable plastic chassis and is powered by four 1.5 volt C cells. The device is intended to operate from this battery supply for approximately two to three weeks including an interval of about a week during which data is actually collected. While not in use, that is when the user is not seated, the logger microprocessor enters a power conserving idle mode that effectively shuts down the processor until awakened by a subsequent interrupt from the seat sensor (1).

The host computer

The host computer for data storage and analysis is an IBM-PC or compatible microcomputer. Data received from the logger is loaded to a file for storage, from which it can be later retrieved for display on a monitor or printer. The associated software has been written in GWBASIC. Particular attention has been given to developing self-explanatory software that minimizes complexity of the technician/analyst's tasks, including host software, that provides the analyst with readily visualized histograms of statistical data at the touch of a computer key (1).

The driver interface

Downloading data from the portable logger to the host computer is accomplished with an RS-232-C communications link through the PC's serial port. Software on the host provides step-by-step instructions for this data transfer. The logger processor handles the entire conversion of data to RS-232-C serial protocol in software, such that the only necessary hardware interface is a single chip driver, for converting the microprocessor's 0/+5 volt positive logic to standard RS-232-C +12/-12 volt negative logic (1).

TESTS AND RESULTS

Two sets of preliminary tests were conducted with the cooperation of disabled volunteers to demonstrate proper operation of the data logger. The first set of data was collected from an Everest & Jennings 3V electric wheelchair operated by a quadraplegic user over a five day period. As confirmed by the operator, the recorded quantities including number of uses, time in use, time in motion, and distance traveled accurately reflected the level of activity experienced during the test. Similarly, the recorded distributions of forward acceleration and velocity, which could not be absolutely verified, appeared reasonable. During the five day test, the data logger recorded no occurence of either tilt or vertical shock. Since only tilts on the order of "wheelies" are measurable, it is reasonable that none were recorded with the electric chair. However, since the user claimed to have encountered at least a few potholes, the lack of shock information suggested some error in the collection of vertical shock data (1).

The second set of data was collected using a lightweight Quadra Fold chair operated by an active paraplegic student at the University of Virginia. As expected, the data collected from a four day test represented an overall higher level of strenuous activity than recorded in the previous electric wheelchair test. The data included more frequent uses per day, greater mobility, measurable shocks, tilt, and more frequent abrupt starts/stops (1).

CONCLUSION

The prototype data logging system generally satisfies data specifications and has been shown capable of recording meaningful information for assessing wheelchair performance in actual use. However, work continues on improving the existing design, with the incorporation of recently available precalibrated shock sensors, and a simplier more easily implemented lever-switch accelerometer. Once the final design is complete, UVA REC intends to manufacture a number of data loggers for conducting reliable surveys of wheelchair activity.

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EXPANSION OF AN EVALUATION PROGRAM FOR ASSISTIVE DEVICES USED BY PEOPLE WITH ARTHRITIS

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INTRODUCTION

According to the Digest of Data on Persons with Disabilities, 26.8 million people are impaired by arthritis; approximately 40% of these individuals are over the age of 65 [1]. A plethora of assistive devices have been created and marketed to help disabled people enhance their daily living and increase their independence. Unfortunately, the majority of these devices lack an evaluation which takes into account design parameters, functional capabilities of the person and therapeutic dimensions.

METHOD

A prototype of an evaluation program was presented at RESNA last year [2] which incorporated marketing, engineering, design, and therapeutic features. Three classifications of people with arthritis were identified: (A) The individual presents no noticeable joint damage, but complains of pain, (B) the individual who presents noticeable joint change/damage related to an arthritis diagnosis, and (C) the individual who possesses severe joint deformity with concomitant muscle atrophy and loss of strength. Three individuals were located, each fitting the description of the mentioned categories.

Assessments were performed along objective and subjective functional criteria to validate the categorization scheme. The three people were found to be exemplary candidates for their respective groups. Five reachers were then used by each individual in a succession of predetermined tasks which emulated common "life" tasks in which one would typically engage.

RESULTS

Problems associated with putting pressure on joints were found for all reachers; many design details appeared to be at odds with good function. Functional applicability as indicated by the capability to perform certain tasks found that more problems were associated with the majority of reachers as arthritis severity increased. Although little differentiation between the five kinds of reachers occurred for the person with little disability (A), only one reacher stood out as appropriate for the individual who was quite disabled (C).

DISCUSSION

It is difficult to generalize to the entire population of people with arthritis; this is not the issue. The various measures do tend to indicate that, at least in the case of reachers, a certain level of disability makes the typical reacher practically useless.

Another component of the present evaluation process which is not included focuses upon the psychological features of the person with a chronic disability. These are important features to take into account *if* the primary goal of an assistive device is to enhance independence and quality of life.

At least three variables need to be assessed when "evaluating" an assistive device. These three variables are related and include: (1) locus of control, (2) helplessness, and (3) self-esteem. Health locus of control [3] may be divided into three types---(A) internal control, where the person believes that there is a linkage between their behavior and their level of health, (B) external control, dependent type, where the individual believes that people in authority are responsible for their health, and (C) external control, fate type, where the individual does not make a link between their behavior and health, that is, "fate" determines their health status.

An interesting interaction may take place between a person's locus of control and usage and perception of the assistive device. Typically, an internal locus of control is viewed as a desirable perspective; however, this may lead to complications because this individual is likely not to want to appear helpless or dependent. This may in turn "backfire" upon the person in the facilitation of joint destruction through poor joint protection activities. Additionally, an individual with this mind set is unlikely to either attain or comply with usage of an assistive device. A similiar outcome may be expected with a person who possesses an external, fate type perspective. The external, dependent type, may be more likely to use such a device because it is incorporated as "good advice."

CONCLUSIONS

Psychological factors need to be taken into account in future evaluation programs of assistive devices. Additionally, these variables need to be correlated with extent of disability as defined by the classification scheme. The information gathered utilizing the present evaluation program may be used to construct a consumer behavior model and identify groups of people where different "helping" strategies need to be developed. Reliance on the idea that the obvious importance and necessity of using an assistive devise is apparent and logical to a person who "needs" one must be abandoned.

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A TOOL FOR QUANTITATIVE ASSESSMENT IN DIAGNOSIS, FOLLOW-UP EVALUATION, AND BASIC RESEARCH

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Samuel Levy, Michael Kary and John Lewis (Diagnospine Research Inc.)

INTRODUCTION

This presentation briefly describes the use of a new system for the collection of objective data on spinal capacity. It measures the position of 24 infrared LED's attached non-invasively to the skin surface, as the subject performs various simple tasks, for which he or she is free to move about without mechanical restriction or interference. EMG signals from up to 16 muscle groups are collected simultaneously. The acquisition rate of the kinematic data is 180 Hz, with an absolute error of about 0.2%. The data collected can be of value not only to the clinician, as an aid in the diagnostic procedure, but also to the basic researcher interested in understanding the nature of human locomotion as well. Here we present examples showing how we have used this data for each of these two purposes. A more detailed explanation can be found in [2].

APPLICATION 1. GAIT ANALYSIS.

Walking is such a natural activity that we often take it for granted. In fact it is often assumed that walking, or running, is simply a matter of "putting one foot in front of the other". It is easy to overlook the complicated mechanics and interactions that, while enabling us to walk with ease, have yet to be recreated in an artificial walking machine (see for example [1,4]). The following example uses data collected via the system described above to illustrate some of the interactions that are commonly overlooked.

The essentials of human bipedal gait

The subject depicted in Fig. 1 was born without arms or legs. Yet, he is able to locomote in a manner that, from the waist up, appears remarkably similar to that of a normal individual. Two questions naturally arise: 1) does objective measurement of the upper-body motions confirm the subjective impression of similarity; and 2) if so, how is this possible?

The basic kinematic data on CS was collected using the LED configuration shown in Fig. 2a, which depicts superimposed images of their positions as recorded at two opposite phases of the gait cycle. A view of the pattern exhibited by a normal subject at two opposite phases of the gait cycle is depicted in Fig. 2b.

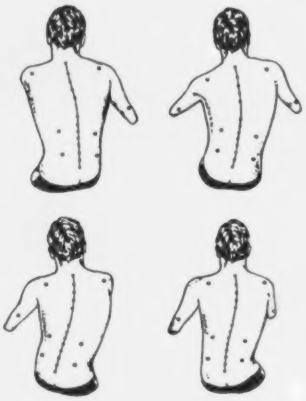

Fig. 1. Subject CS, born with no arms and no legs, walks on his pelvis.

Note that both subjects exhibit the same characteristic S-shaped lateral bending pattern during locomotion. This is inconsistent with the view that the upper-body motions are simply a reaction to, or a compensation for, the motions of the legs. On the other hand we have proposed a theory [2,3] wherein the spine and its surrounding soft tissues constitute the primary engine of the pelvic motions, which the legs serve to amplify. A complete discussion of the relationship between CS's walking pattern and that of a normal subject (including joint displacement comparisons) can be found in [2].

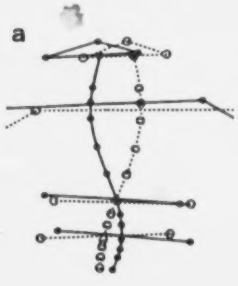

Fig. 2 a) LED configuration (back view) of CS at two extremes of the gait cycle. Note the characteristic S-shaped motion of the spine. b) Back view of pattern exhibited by a normal subject (spinal LEDs only) at two opposite phases of the gait cycle (width scaling has been exaggerated as the motions of the normal subject are not as pronounced as those of CS). Note the marked similarity.

APPLICATION 2. ON-LINE EVALUATION OF THE OPTIMUM DURATION OF A PHYSIOTHERAPY PROGRAMME

The accuracy and repeatability (i.e the low between-trial variability) of the data collected [2] provide the opportunity for on-line assessment of the benefits of a physiotherapy regime. The patient can be evaluated on a regular (e.g. weekly or bi-weekly) basis through the course of his or her physiotherapy programme, and treatments continued until the point where the patient no longer demonstrates any significant improvements in range of motion or joint mobility. Of the many parameters measured, the variation in the degree of lordosis (lumbosacral angle) as the patient bends forward is of particular importance (the theoretical reasons for the selection of this parameter are explained in [2]). An example of how it can be used to monitor the course of a physiotherapy programme is given below.

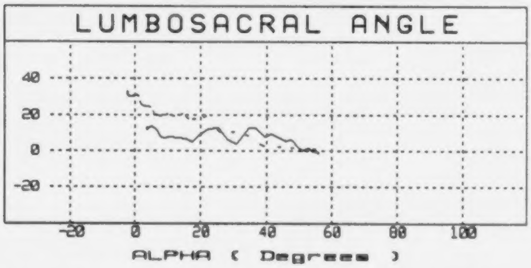

Fig. 3. Patient MR, first visit after injury. Lack of change in lumbosacral angle as the patient bends forward is an abnormal response. See [2].

Fig. 3 shows a plot of lumbosacral angle vs. angle of forward bending for patient MR's first visit. The response is almost constant, which is abnormal and indicative of a restriction on joint mobility. A physiotherapy programme was initiated. Fig. 4 shows a plot of the same measurements collected during his second visit, 2 weeks later.

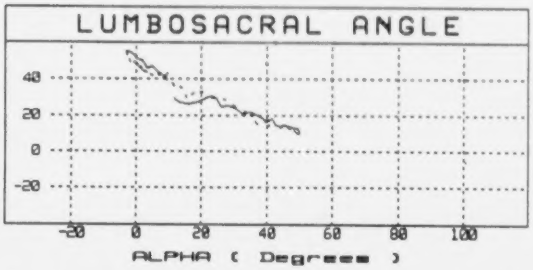

Fig. 4. Patient MR, second visit. After two weeks of physiotherapy, response shows considerable improvement.

Note the marked increase in the range of lordosis variation. By the third visit, little change was evidenced and the response was normal. The response exhibited during the fourth visit (Fig. 5) was not significantly different from that of the third visit two weeks earlier, suggesting that functional capacity had been regained. Thus it appears that at least part of the last two weeks of physiotherapy were not necessary.

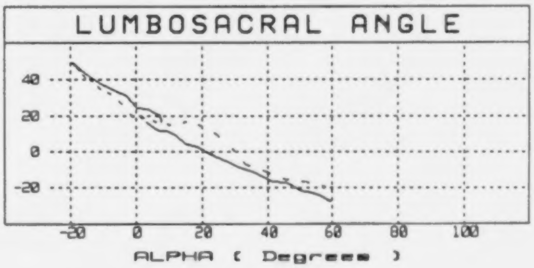

Fig. 5. Patient MR, fourth visit. Almost no change occurred between the third and fourth visits, and the response is normal.

CONCLUSION

The type of data described above can be effectively used for on-line monitoring of the effectiveness and optimal duration of physiotherapy programmes. The nature and accuracy of this objective information is also useful for the basic researcher investigating the fundamentals of human locomotion and spinal biomechanics.

ACKNOWLEDGEMENTS

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TESTING THE ACCURACY OF THE VERMONT REC PREDICTIVE RISK MODEL OF LOW BACK PAIN ON TWO DIFFERENT POPULATIONS

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ABSTRACT

The purpose of this study was to test the predictive accuracy of the Vermont REC Predictive Risk Model of LBP disability on two population samples with very different socio-economic demographics. Disability as predicted by the model was compared to actual disability assessed 3 and 6 months later and to disability predictions made by the attending specialists. The model showed a higher predictive accuracy than the physicians and performed equally well on both samples.

INTRODUCTION

Low back pain (LBP) affects from 40% to 80% of individuals at some time during their lives and it has been estimated that fifty percent of these will experience recurring problems with the lower back [1]. For some, low back pain is a minor, isolated inconvenience having little effect on their daily lives. For others, the pain may be severe enough to impair their ability to work and carry on usual daily functions.

While LBP is not a visible handicap, the seriousness and pervasiveness of LBP is evident (an estimated 11.7 million LBP impaired and 5.3 million LBP-disabled in the USA [1] with associated costs in the billions of dollars). Although 90% of LBP sufferers improve spontaneously within 4 to 8 weeks, the remaining 10% will become disabled. Those who are disabled more than 6 months account for 90% of the costs. The need for accurate measures of the likelihood of becoming disabled is apparent. The Vermont Rehabilitation Engineering Center is addressing this growing socioeconomic problem by studying factors associated with early detection and prediction LBP disability. We have reported elsewhere the development and implementation of a multi-attribute utility model that predicts disability with a high level of accuracy comparable to that of specialists in the field [2]. The objective of the study reported here was to further test the model. The question to be answered was how accurate and robust the performance of the predictive model is across different populations.

METHODOLOGY

The predictive model has been described elsewhere. It suffices to say here that the predictive model consists of 28 factors determined by consensus of a panel of experts and weighted by statistical significance using discriminant function analysis [2]. To measure the performance of the model we have implemented it in the form of a computerized questionnaire [3] at the Vermont Low Back Clinic in Burlington, Vermont, and at the Alamo Bone and Joint Clinic in San Antonio, Texas. The version of the questionnaire implemented at the Texas clinic was delivered in both English and in the region's Spanish vernacular. At both locations the questionnaire was administered to all patients entering the clinics via a computer with a touchscreen format. The advantages of such format have been discussed before in detail (3). Each subject's file consisted of the responses to the questionnaire, a physician's report and his/her estimate of the subject's likelihood of becoming disabled, and 3 and 6 months follow-up data on the work status of the subject. The predictive risk model scores each subject on 28 factors organized into eight categories (job, psychosocial, injury, diagnostic, demographic, medical history and anthropometric factors), which are then combined into an overall score ranging from 0 to 1 (where 0 = unlikely, 1 = very likely to become disabled).

DATA

The Texas and Vermont samples consisted of 72 and and 99 valid cases respectively. The profiles of the two samples were found to stand in marked contrast. The Texas sample is about 6 years younger, significantly more male, and has a lower median income and median level of education. In response to questions measuring self-efficacy, the Texas sample displayed a greater propensity toward predicting ultimate disability. The Texas sample also shows a higher mean level of self-reported pain at the time the questionnaire was administered. Of the most dramatic contrasts is the great percent of the Texas sample that have contacted a lawyer concerning their ailment, and the overwhelming belief that the problem is compensable. There are also significant job related differences that reflect a lower number of unemployed in Vermont, and a lesser preference for keeping the current job, a less stable work force, and a stronger preference for disability compared to keeping the current job in the Texas sample (see Table 1).

RESULTS

We then looked at the model's classification outcomes at 3 and 6 months for the Vermont sample. The 6 month work status of the Texas sample is still being collected but we have found previously a consistently high correlation of 0.95 between the 3 and 6 month status in all samples, and so have used the 3 month work status figures for this analysis. 83% of the patients in the Texas sample were actually disabled at 3 months whereas only 11% of the Vermont sample were. The predictive accuracy of the model was 80% for the Texas sample and 85% for the Vermont sample, and in both cases higher than the predictive accuracy of the physicians. A discriminant function analysis confirmed the results obtained from previous samples, in identifying job characteristics, past hospitalizations, level of education and smoking as strong predictive factors.

CONCLUSIONS

Despite the great contrast in these two samples, the predictive model demonstrated a stable and high predictive accuracy. These results support our basic hypothesis that LBP disability can be predicted. One of our goals is to continue the testing of the questionnaire in a variety of geo- and sociodemographic settings. Another goal is the development and testing of a much shorter paper-and-pencil version of the computerized questionnaire suitable to be applied in a primary-care setting. This goal reflects our belief that early identification is key in being able to intervene effectively and prevent disability. Preliminary results on the accuracy of the paper-and-pencil version are encouraging.

Table 1. Comparison of data collected at the Alamo Bone and Joint Clinic and the Vermont REC.

Variable	Vermont REC	Texas	
Number of responses	99	72	
Mean current pain level	4.4	6.2	***
Male	51.5%	63.3%	***
Age (mean/range)	37.5 (18-60)	31.3 (17-63)	**
Less than High School	12.1%	44.4%	***
Income:			***
<$10,000	9.1%	34.7%	
$10,000-$20,000	33.3%	54.2%	
$20,000-$50,000	48.5%	9.7%	
>$50,000	9.1%	1.4%	
Work Status:			***
Employed	86.9%	84.7%	
Self-Employed	12.1%	1.4%	
Unemployed	1.0%	13.9%	
Less than 1 year at current or most recent job	23.2%	47.2%	***
Less than 1 year at job before that	16.2%	31.9%	***
Self-assessment of whether patient will be working in 6 months (1-10)	8.3	5.5	**
Mean job satisfaction (1-10)	6.8	7.1	*
Work status preference for:			***
Work at current job	78.8%	63.9%	
Work at different job	17.2%	26.4%	
Retire	4.0%	1.4%	
Receive disability	0.0%	8.3%	
Income source preference:			***
Work	97.0%	86.1%	
Retire	2.0%	0.0%	
Collect disability	1.0%	13.9%	
Believes problem compensable	34.5%	93.1%	
Has contacted lawyer	7.1%	87.5%	***
Perceived Blame:			***
Self	16.2%	4.2%	
Work	27.3%	70.8%	
Other	29.3%	11.1%	
No one	27.3%	13.9%	
Hassles score	21.2	28.0	**
Hopkins score	84.2	97.7	***

*** $p < 0.01$
** $p < 0.05$
* $p < 0.10$

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FUNCTIONAL RESTORATION WITH BEHAVIORAL SUPPORT: A ONE-YEAR PROSPECTIVE STUDY OF CHRONIC LOW BACK PAIN PATIENTS.

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INTRODUCTION

The recognition of chronic low back pain as a complex syndrome of biopsychosocial issues has produced a wide range of multidisciplinary treatment programs. In 1985, Mayer et al. reported excellent return-to-work outcomes using an innovative program of functional restoration and behavioral support guided by physical capacity measurements (1). The current study prospectively tested the efficacy of such a program in a different geosocioeconomic setting and compared one year work status outcomes with psychosocial and physical attributes of program participants and a control group.

METHODS

The study involved all patients (90) referred to the program with low back pain and/or sciatica causing at least four months continuous total disability, no clear indication for spinal surgery and no evident psychosis or severe characterologic disorder precluding participation in group treatment. Sixty-four patients entered the program, while 20 who were accepted but denied entry by their insurance carriers became the control. Six patients were denied entry for over six months before admission, forming a crossover group. The program included three weeks of full-time physical training and psychological and occupational counseling, followed by an average of three weeks of part-time treatment. Biopsychosocial measures were recorded for all patients upon entry into the study and follow-up measures were recorded for program graduates at discharge, six weeks, three months and at least one year. All patients unavailable for direct testing at year end were evaluated by telephone. Crossovers were evaluated at six months.

RESULTS

Program graduates averaged 37 years of age, 20 months continuous total disability, .4 spinal operations and 1.0 medications. Sixty-four percent were male and 91% were receiving worker compensation. Initial mean scores for this group were as follows: Millon pain analogue (MPA) = 93; Oswestry pain questionnaire (OPQ) = 39; Beck Depression Inventory (BDI) = 11.9; sagittal trunk motion (ROM) = 93 degrees; repetitive lifting (LIFT) = 29 lbs.; isokinetic trunk flexion (ITF) and extension (ITE) = 62 and 64%t/bw, respectively. There were no significant differences between program graduates (59), program dropouts (6), program denials (20) and crossovers (6) for any of these factors ($p > 0.10$) except worker compensation ($p=0.042$) and MPA ($p=0.065$). After a minimum one-year follow-up, return-to-work rates were: 81% for program graduates, 40% for program dropouts, and 30% for program denials. Six months after treatment, all six crossover patients were working. After three weeks of treatment, program graduates showed the following mean improvements: -24 MPA, -14 OPQ, -6 BDI, +34 degrees ROM, +35 lbs. LIFT, +15%t/bw ITF, and +26%t/bw ITE. At the one-year follow-up, there was no difference in initial scores or in improvement scores between those who were working and those who were not.

CONCLUSION

While the program was successful in returning chronic low back patients to work, biopsychosocial attributes were found to be poor predictors of work status one year later. Year-end attributes are currently being correlated with work status in an effort to clarify the occupational impact and duration of treatment effects.

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A COMPARATIVE ANALYSIS OF POSTOPERATIVE DISCECTOMY TRUNK STRENGTH AND ENDURANCE

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Following surgical discectomy the relief of radicular pain is predictable and reliable. However, many of these patients report persistent or recurrent nagging backache and stiffness postoperatively which often delays their return to normal activities. It is widely believed that this postoperative pain is due to muscular and/or mechanical alterations. Unfortunately there is relatively little data to support this. This study was performed to identify specific alterations in the back muscle strength and endurance of patients undergoing surgical discectomy. The study consisted of 44 patients (23 women and 21 men) undergoing a one level discectomy performed by the same surgeon. Each patient underwent testing an average of 37 days postoperative. The test battery consisted of previously described isometric, isokinetic and endurance tests (1,2, 3,4). Preoperative testing was not done because of the limiting nature of the preoperative sciatic pain. Mean maximum torque was 55 Nm in flexion and 67 Nm in extension in the postoperative male group. Normal mean values are 169 Nm in flexion and 210 Nm in extension (1). Mean values for postoperative females was 30 Nm in flexion and 37 Nm in extension. Normal mean female values 61 Nm in flexion and 98 Nm in extension (4). The postoperative mean male value was 109 Nm for flexion and 107 Nm for extension. Normal mean male values are 137 Nm and 212 Nm for flexion and extension (2). The postoperative mean female value was 52 Nm for flexion and 56 Nm for extension. Normal mean female values are 111 Nm and 122 Nm for flexion and extension (4). Endurance was tested using a modified Sorensen test. The postoperative mean value was 51 seconds. The postoperative mean female value was 68 seconds.

Postoperative male patients had 68% less strength in both isometric flexion and extension compared to normals. Postoperative female patients showed a similar decrease in both isometric flexion strength (50%) and isometric extension strength (62%) compared to normals. Similarly, postoperative male isokinetic strength was 55% less in flexion and 71% less in extension than normals. Postoperative isokinetic strength was 71% less in flexion and 69% less in extension in the female group compared to normals. Although it is probably impossible to determine the extent of weakness prior to surgery, it is statistically significant and quite clear that there is a dramatic loss of normal strength in the immediate postoperative period in both male and female patients undergoing surgical discectomy compared to normals. This data establishes valid criteria by which a specific postoperative strengthening program may be designed. By specifically designing the postoperative rehabilitation program to increase these abnormal parameters, objective measures of improvement may be monitored with this comprehensive and easily reproducible test battery.

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QUANTITATIVE EVALUATION OF THE RANGES OF HEAD MOTION FOR NORMAL ADULTS AND FOR PATIENTS WITH NECK INJURIES

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Abstract

This paper presents the results of the use of the hemispherical shell method for the measurement of head motion for patients with neck injuries and also for normal adults. The results obtained with the presented method are compared with the results from the previous methods. The residual available head motion of patients with neck injuries is obtained which will be useful in the individualized design of instruments such as headstick operated keyboards or keyboard like devices.

Introduction

The measurement of the ranges of head motion is of interest in the treatment and rehabilitation of patients with neck injuries. The accurate measurement of head motion is complicated due to the fact that the complete motion of the head and neck system is provided by 23 separate articulations in the cervical spine. Moreover, there are problems in the selection of good reference points for the relatively spherical head. The complete description of the head movement requires six independent parameters, but for our study, three angular orientations of the head are chosen adequate for the purpose of comparisons and clinical evaluation of these patients. The three motions are flexion and extension in the sagittal plane, lateral bending in the frontal plane and rotation in the transverse plane.

Traditionally several methods have been used to measure the head motion. Defibaugh [3] has done an excellent review of the various methods. These methods are either too complex or do not provide the measurement of all the three degrees-of-freedom at any given position of the head. These methods mostly consist of the use of X-rays, goniometers, photography and manipulators. The hemispherical shell method for the measurement of head motion has been described in a previous paper (1). The objective of this paper is to demonstrate the usefulness of that technique for the measurement of the ranges of head motion for patients with neck injuries in a clinical setting. The results obtained in our study are compared with the results obtained by previous methods.

Instrumentation

The system used here consists of a hemispherical shell mounted with the help of a frame over the head of the patient (1,2). Two light sources consisting of two lights and a lightweight head strap are mounted on the patient's head and readings are taken from circular scales marked on the outer shell surface. These lines, marked as two protractors, represent degree measures and are continued across the entire shell surface.

Methodology

The patient sitting on a wheelchair or a regular chair is moved to the frame and the chest of the patient is strapped to the back support of the frame. The head strap with the light source is placed on the patient's head so that the two lights are equally spaced from the centerline of the patient's head. The patient is then asked to hold his head in a position which he feels is a normal position. For a healthy subject, this will be a vertical position. This defines the position from which all deflections - flexion, extension; lateral bending and rotation are measured. We define two types of motion, major and minor. For example if a subject has his head flexed fully forward and is looking downward, then theoretically there is no lateral bending or rotation. For this case the flexion is the major motion accompanied by a few degrees of rotation and few degrees of lateral bending, which are the minor motions. If a subject has his head flexed laterally and is looking forward, theoretically there is no rotation or flexion and extension. If the maximum flexion in the sagittal plane is to be determined, then the patient is asked to bend his head in a forward position as far as possible and four readings are taken from the two scales on the shell surface. Analytical equations [1] are then used with the help of a microcomputer to convert the data obtained from these two scales. Similar procedure is performed for each of the five other primary positions of the head. This information is then used to determine the maximum ranges for the three angular motions of the head for any patient.

Subjects

Subjects in this study were normal men and women and patients with neck injuries. Ranges of head motion were determined for 19 normal men ranging in age from 19 to 50 years and for 7 normal females ranging in age from 20 to 32. There were 14 subjects with neck injuries. Their ages ranged from 19 to 49. There were 12 male subjects and two female subjects. 12 of the subjects had cerebral palsy and two suffered from muscular dystrophy.

Results

The results of this study as illustrated in Table 1 indicate that the normal range of head motion for males with average age of 29.2 years is 140.5 degrees for flexion-extension, 113.8 degrees for lateral bending and 145.8 degrees of rotation. These values for women with average age of 24.6 years were 151.3 degrees of flexion-extension, 118.1 degrees of lateral bending and 149.4 degrees of rotation. This study indicates that the ranges of angular head motion for women are slightly higher than for men. This is in agreement with the results achieved by Buck [6].

Table 2 compares the results obtained in the present study with those obtained by previous researchers, Buck [6], Defibaugh [3] and Leighton [7]. All these studies were done on healthy subjects. The results obtained in the present study on flexion- extension and rotation for both men and women are in very close agreement with the results obtained by Buck [6]. Buck measured all motions while subjects were sitting on a straight back chair. Therefore the positioning of the subjects and also the age group were similar to our study.

Group	No.	Av. Age	Angle Measured - degrees								
			Flexion-Extension			Lateral Bending			Rotation		
			Range	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.
Normal Male	19	29.2	92-168	140.5	19.5	74-149	113.8	22.7	114-167	145.8	14.5
Normal Female	7	24.6	127-164	151.3	13.1	85-145	118.1	20	135-162	149.4	8.6
Subjs. with CP	12	32.6	74-161	126.3	22.7	44-152	86.4	39	87-140	111.9	18.3

.Table 1 Range of Voluntary Head Motion

	Angles in Degrees					
	Present Study		Buck		Defibaugh	Leighton
	Males	Females	Males	Females	Males	Males
Flexion-Extension	140.5	151.3	139	150	137	127
Lateral Bending	113.8	118.1			91	98
Rotation	145.8	149.4	145	147	168	159

Table 2 Comparison of Head Motion Ranges in Different Studies

The study by Leighton [7] shows lower values on flexion-extension and lateral bending but a higher mean value on rotation. Leighton had a mean value of 127 degrees for flexion-extension in males as compared to 140.5 degrees determined in our study. Lateral bending was 98 degrees in Leighton study as compared to 113.8 degrees in our study. On the other hand, he found a rotation of 159 degrees as compared to 145.8 degrees in our study. These differences have occured, perhaps due to the fact that Leighton measured flexion-extension and rotation while subjects were supine. Moreover his subjects had an average age of 18 years as compared to an average age of 29.2 years in our study. Leighton study shows less flexibility in adolescent boys as compared to men as far as flexion-extension and lateral bending are concerned. On the other hand, boys seem to have more flexibility than men as far as rotation is concerned.

Our study indicates that the 12 subjects with cerebral palsy had a mean value of flexion-extension of 126.3 degrees, lateral bending of 86.4 degrees and rotation of 111.9 degrees. These values indicate that these patients, due to disability, have considerable less cervical mobility as compared to healthy subjects. The variability in the ranges of head motion for patients with cerebral palsy was wider than for normal subjects. The data shows a higher standard deviation for all the three head motions of cerebral palsy patients relative to the standard deviation values for the normal people. Some of these patients had a higher value of angular head motion because of lack of muscle control. Due to the stability problems many of these patients will not be able to utilize the larger values of available head motion to perform useful tasks with head sticks or mouth sticks. We also tested two patients with muscular dystrophy. Their ranges of angular head motion were very limited. One of the patients had almost negligible lateral bending motion. The patients with MD had flexion-extension motion of less than one-third of the identical motion range for normal people.

Conclusions

Presented in this paper are the results of the use of the hemispherical shell method for the measurement of the head motion for patients with neck injuries. This study has demonstrated that the ranges of head motion for healthy subjects determined with the hemispherical shell method are in close agreement with the results obtained by previous researchers. Hence we conclude that the data obtained with the new method on the head motion of patients with neck injuries is fairly accurate and can be used to evaluate their disability. This data will also be useful in the individualized design of instruments such as headstick operated keyboards or keyboard like devices. The proposed technique can also be used to study the flexibility in the cervical spine of athletes.

Acknowledgements

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MEASURING SYSTEM OF THREE-DIMENSIONAL ANGULAR DISPLACEMENT OF PELVIS BY ANGULAR RATE SENSOR

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INTRODUCTION

The angular displacement of pelvis during walking is one of the most important kinetic information for rehabilitation. To measure it, stereometric methods using stereo-photogrammetric technique or stereosonic system have been studied so far. Such systems are, however, quite large and need long time for data processing to be used for clinical application. In this paper a new system of the three-dimensional angular displacement of pelvis during walking is discussed: it uses angular sensors and needs a little time for processing. With this system angular displacements of normal persons as well as patients with hip joint disorders have been analyzed and compared. This system can be used for the quantitative gait evaluation.

MEASURING SYSTEM

The block diagram of this measuring system is shown in Fig. 1: it consists of sensor part and data processing part. Sensor part contains three kinds of sensors to detect absolute angular displacement of pelvis (inclinometer) in sagittal and frontal planes, angular rate of pelvis (angular rate sensor) in transversal plane and foot-floor contact sequences during walking. Angular rate data is numerically integrated to obtain angle displacement in transversal plane. The two-dimensional inclinometers and angular rate sensor (Watson Industries Inc.) utilize piezo-electric vibrating beam technology, can provide angle or angular rate data like rate gyro. Their weight is 900 g and the size is 8.8x7.5x15 cm. As these angular sensor are installed at the pelvis on the back by corset, derived data are presented by the coordinates of pelvis. A pair of foot switch sensors made of pressure-sensitive conductive rubber detect the foot-floor contact state. Data derived from these three kinds of sensors are fed to micro-computer NEC PC-9801VM through analog-to-digital converter or digital I/O unit.

DATA PROCESSING

The angle and angular rate data measured in pelvic coordinates is transformed to data in space coordinates observed by PT (Physiotherapist) as follows.

$$\psi' = \int \omega \times \cos(\arctan\sqrt{(\tan^2\theta+\tan^2\phi)})dt \quad (1)$$

$$\theta' = \arctan(\tan\theta\cos\psi+\tan\phi\sin\psi) \quad (2)$$

$$\phi' = \arctan(\tan\phi\cos\psi-\tan\theta\sin\psi) \quad (3)$$

where ω : angular rate in transversal plane
θ, ϕ, ψ : angle in sagittal, frontal, and transversal plane
$'$ denotes transformed data

The obtained data is first separated into segment by every heel strike instance and all of the segments are superimposed after being time-normalized to 100 % for one stride. Strides starting with right heel strike and left heel strike are displayed together in the figure: solid line presents right-leg-support period and broken line presents left-leg-support period and small circles mean heel strikes. All the above processing needs about 15 seconds after data acquisition, so subjects and PT. don't have to wait any time.

The angular data can be characterized by four check points about the waveform as follows.

1. (1) repeatability of cycle
2. (2) peak-to-peak amplitude
3. (3) comparison between waveform of the right-leg-support period and the left-leg-support period
4. (4) number of extreme points and their times in a cycle

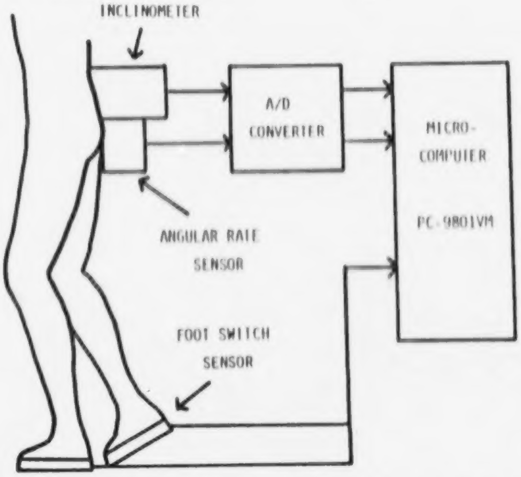

Fig. 1. The block diagram of measuring system.

RESULTS

Pelvic angular displacement of a normal person and a woman who has a disorder of osteoarthritis at her right hip joint and got surgical operation, THR(Total Hip Replacement), is measured. Results of this measuring after being processed are shown in Fig. 2: the patient is measured at one month (data(a)) and two months (data(b)) after operation. The characteristic of these data and comparison of three cases especially regarding check point (4), (extreme point) is given as follows.

(1) In sagittal plane:while normal person's data have a peak both at right and left heel strikes(1-a), there is no peak at right heel strike damaged side, in the patient data waveform(2-a). At two months operation, small peaks appear(3-a).

(2) In frontal plane:while waveform of normal person data has two peaks for every one step period(1-b), but patient data(b) has only one peak. Two peaks for every one step period appear two months after operation (3-b).

(3) In transversal plane: while there are sharp extreme points in the normal person data waveform at every heel strike(1-c), there is no peak but a form keeping a constant angle in the patient data(a) at the right heel strike damaged side(2-c). At two months after operation, the period keeping a constant angle becomes shorter(3-c).

Analyzed on the four check points, patient's pelvic angular displacement has more characteristics of normal person as time passed after operation.

CONCLUSIONS

Measuring system for the three-dimensional angular displacement of pelvis during walking is developed. It is lightweight and needs a little time for processing. Data acquired from normal subjects and patients have been characterized by the proposed four check points with regard to the waveform. It has been shown that these four points can reveal the differences between them. As the system is compact and easy to handle, it can be used in clinical application.

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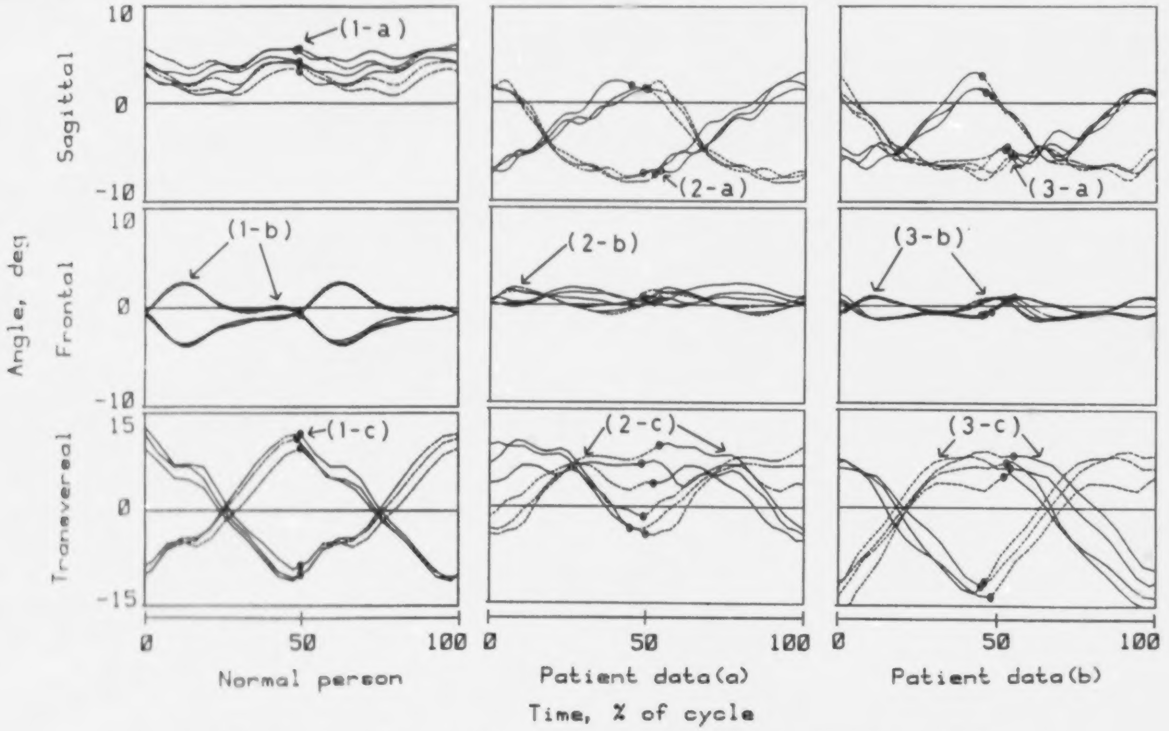

Fig. 2. Measured angular displacement of pelvis during walking.

CONSTRUCTION OF TENSION-LENGTH RELATION CURVE OF HUMAN UPPER EXTREMITY MUSCLES

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INTRODUCTION

Three major architectural components are necessary to estimate individual muscle force generation capacity: The functional cross-sectional area, i.e., the number or sarcomeres in parallel, is related to the tension the muscle can produce. A second component is the length of the fibers which determines the shortening velocity. The third component is the angle of pennation of muscle fibers.

The amount of tension generated also depends on muscle length. The tension-length relation has been demostrated at the sarcomere level, isolated animal muscle level, and for intact muscle of live human subject.

The purpose of the present study was to develop a method to construct the tension-length curve of individual muscles based on architectural data.

METHODS

Four white male cadavers were used. Twelve muscles: Anterior Deltoid (DA), Middle Deltoid (DM), Posterior Deltoid (DP), Pectoralis Major-clavicular part (PC), Pectoralis Major-sternal part (PS), Biceps Brachii-long head (BBL), Biceps Brachii-short head (BBS), Brachialis (B), Brachioradialis (BR), Triceps Brachii-long head (TBO), Triceps Brachii-lateral head (TBA), and Triceps Brachii-medium head (TBM), of both upper-extremities of each cadaver were studied.

Insertion-origin length (IOL) was measured from the mid-point of the insertion area to the mid-point of the origin area for each muscle. Muscle volumes were determined using water displacement. Skeletal links (LL) were determined. The angles (θ) formed by the individual muscle bundles with the action line of the whole muscle were measured at several representative locations. These bundles were then dissected from each muscle and their lengths (BL) were measured. Bundles were isolated and 4 single fibers were teased from each bundle. Fiber length (FL) was measured. Single fibers were mounted on microslides and were examined under a light microscope (400X) connected to an image processing system. Five to ten intervals were counted for each fiber, and the sarcomere number (Si) as well as the interval length (Di) were recorded.

The values of average sarcomere length (ASLf), sarcomere number per fiber (SNf), average sarcomere number (ASNb), normalized fiber length (NFLb), functional normalized fiber length (FNFLb), functional bundle length (FBLb), average functional normalized fiber length (AFNFm), functional physiological cross-sectional area (FXSAm), average functional bundle length (AFBLm), tendon length (TLm), and, optimal insertion-origin length (OIOLm) were determined from the measurements described above in the following calculations.

$$ASL_f = \sum_{i=1}^{n} D_i \,/ \sum_{i=1}^{n} S_i$$

$$SN_f = FL_f \,/\, ASL_f$$

$$ASN_b = (\sum_{f=1}^{nf} SN_f) \,/\, n_f$$

$$NFL_b = ASN_b * 2.2\ \mu m$$

$$FNFL_b = NFL_b * \cos\theta_b * \cos\sigma_b$$

$$AFNFL_m = (\sum_{m=1}^{n_b} FNFL_m) \,/\, n_b$$

$$FBL_b = BL_b * \cos\theta_b * \cos\sigma_b$$

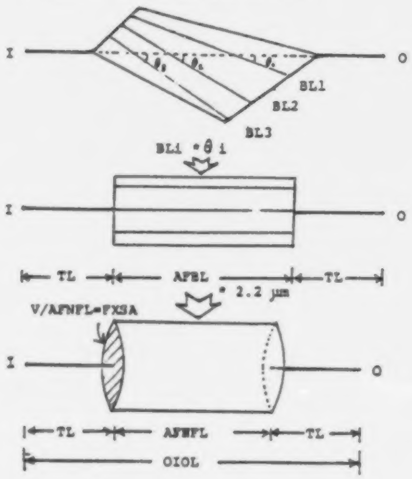
$$AFBL_m = (\sum_{b=1}^{nb} FBL_b) \,/\, n_b$$

$$TL_m = IOL_m - AFBL_m$$

$$OIOL_m = TL_m + AFNFL_m$$

$$FXSA_m = V_m \,/\, AFNFL_m$$

Figure 1. Transformation of data



Variables are summarized in Figure 1.

A tension-length (T-L) curve for brichialis m. is presented in Figure 2. The curve is based on a maximal specific tension capacity for FXSA of 29 N/cm^2.

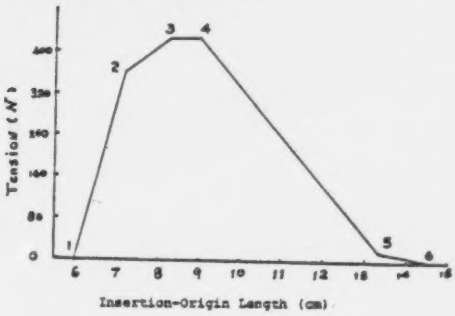
Figure 2. Construction of the Tension-Length Diagram of Brachialis

A. Sarcomere data ---> IOL-Tension data

IOL = (ASN * SL) + TL
Tension = Y% * (29N/cm^2) * FXSA

1. (1.27 , 0%) (6.0 , 0)
2. (1.67 , 84%) (7.2 , 360)
3. (2.00 ,100%) (8.3 , 429)
4. (2.25 ,100%) (9.0 , 429)
5. (3.65 , 5%) (13.4 , 21)
6. (4.00 , 0%) (14.5 , 0)

B. Tension-Length Curve of Brachialis



RESULTS

Architectural data for twelve human upper-extremity muscles are presented in Table 1.

Table 1. Architectural Features of the Human Upper-Extremity Muscles

	V (ml) Mean (SD)	FXSA (cm2) Mean (SD)	ANFL (cm) Mean (SD)	OIOL (cm) Mean (SD)	OIOL/LL Mean (SD)
DA	79 (20)	9.9 (3.2)	8.1 (1.2)	13.9 (.8)	.446 (.033)
DM	135 (38)	21.0 (5.2)	6.4 (.8)	12.4 (1.3)	.399 (.053)
DP	104 (24)	10.8 (3.2)	9.8 (1.5)	16.9 (1.4)	.541 (.040)
PC	48 (15)	3.8 (1.5)	12.7 (1.6)	12.6 (1.2)	.404 (.033)
PS	187 (52)	13.8 (5.7)	14.1 (1.8)	18.5 (1.0)	.592 (.039)
BBL	71 (23)	7.7 (3.2)	9.6 (1.8)	33.2 (1.8)	1.058 (.083)
BBS	46 (8)	3.9 (.6)	11.6 (1.6)	30.8 (2.1)	.970 (.100)
BR	39 (10)	3.2 (.8)	12.1 (2.4)	24.7 (2.1)	.890 (.041)
B	93 (28)	14.8 (4.6)	6.9 (1.5)	8.9 (.6)	.325 (.027)
TRM	88 (27)	13.6 (5.5)	7.1 (1.8)	23.9 (1.8)	.776 (.050)
TRO	132 (28)	16.1 (6.8)	8.8 (1.6)	29.2 (2.4)	.935 (.065)
TOM	94 (20)	15.1 (4.0)	6.3 (.8)	12.6 (.8)	.404 (.007)

DISCUSSION

This study presented a logic and serviceable method to collect anatomic data from cadavers with potential to predict the performance of the muscles. FXSA, ANFL, and OIOL were used to construct the tension-length relation curve shown in Figure 2.

The x-axis of T-L relation curve is IOL, and not the muscle length used in previous studies. IOLs can be determined from live subjects for different joint-angle conditions and the OIOLs of individual muscles can be estimated with acceptable accuracy using the means of OIOLs (1 SD ≤ 10%) from this study directly or using the OIOL/LL ratios (1 SD ≤ 13%) and LLs from live subjects. The T-L relation curves constructed by this method are more specific to individual subjects and particular conditions than those reported in previous studies.

There was substantial variance (1 SD =19%-41%) of FXSAs, used to determine the maximal tension potential along the y-axis of T-L curve, for muscles from different extremities. The direct application of these values would result in an unacceptable error. Magnetic resonance imaging could be used to estimate the muscle volumes from live subjects and to provide a basis for determining individual values for FXSAs.

The constructed T-L relation curves provide useful information, such as maximal isometric potential and physiological length range of muscles, and, furthermore, they can be examined and modified under controlled experimental conditions in future research.

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DETERMINATION OF ATTACHMENT LOCATIONS OF HUMAN UPPER EXTREMITY MUSCLES

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INTRODUCTION

Precise quantitative anatomical data are necessary for the biomechanical modeling of the musculoskeletal system. Muscle origin, insertion and action line, for example, are required for the calculation of the moment arm and the force vectors for individual muscles at different joint angle positions (1,2,3). Various methods are used to quantify these anatomical parameters. External manual palpation of live subjects is inadequate to detect the origin and insertion of the deeper muscles and is subject to considerable error when used to measure the superfical muscles (4,5). Other methods, such as X-ray, CT and direct load measurement method (1,3), are either too expensive or provide limited information. The most accurate way to measure the origins and insertions of muscles is through careful cadaver dissection, but the information derived from this method usually cannot be applied directly to living subjects. The purpose of the present study was to determine if there are consistent proportionalities in the dimensions of links to muscle attachments that could be used to estimate these variables for individual subjects from easily measured anthropometric parameters.

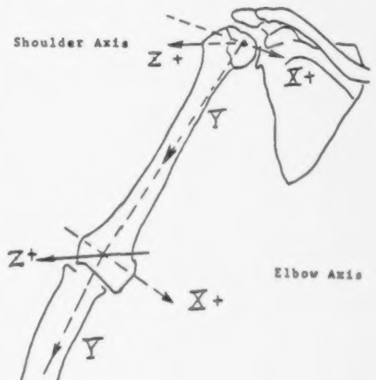
METHODS

Four white male cadavers were used in the present study. The muscles were dissected from both upper extremities of each cadaver in the following order: 1) Anterior Deltoid (DA), 2) Middle Deltoid (DM), 3) Posterior Deltoid (DP), 4) Pectoralis Major-clavicular part (PC), 5) Pectoralis Major-sternal part (PS), 6) Biceps Brachii-long head (BBL), 7) Biceps Brachii-short head (BBS), 8) Triceps Brachii-long head (TBO), 9) Triceps Brachii-lateral head (TBA), 10) Triceps Brachii-medial head (TBM), 11) Brachioradialis (BR), 12) Brachialis (B).

The extraction of the muscles from bones was done keeping the joint capsule as intact as possible. Attachment areas were marked on bones using a pencil and the mid-points of attachment areas were estimated visually.

After all the muscles were removed from the cadaver, the cadaver was positioned on a custom design frame in a sitting posture with both arms pendant beside the trunk, elbow in 90 degrees flexion and forearm in semipronation. A left-handed orthogonal coordinate system with the origin placed at the center of the humeral head was used for the right upper extremity and a right-handed orthogonal coordinate system was used for the left side. The x-axis passed horizontally through both humeral heads, the y-axis was vertical running in the cranio-caudal direction and aligned with the humeral link, and the z-axis was orthogonal. For the elbow joint, the x-axis passed through lateral and medial epicondyles, the y-axis ran through the central line of forearm, the z-axis was orthogonal, and the origin was placed at the mid-point of line connecting lateral and medial epicondyles. Figure 1 depicts the left-handed orthogonal system.

Figure 1. Left-handed Orthogonal Coordinate System



The lengths of arm and forearm links were measured using an anthropometric caliper. The x-coordinates and z-coordinates of the origins and insertions of the twelve muscles were measured and recorded in relation to the shoulder axis or elbow axis. The y-coordinates of the origins (OY) and insertions (IY) were the distances measured from the attachment to the farther end of the link to minimize the measurement error. The ratios of y-coordinate and link length for origins (OY/BLO) and insertions (IY/BLI) of twelve muscles were then calculated.

RESULTS

A summary of the results is presented in Table 1 which includes the mean, range, and standard deviation for the ratio of each muscle.

TABLE 1. RATIOS OF Y-COORDINATE AND LINK LENGTH

	IY/BLI		OY/BLO	
MUSCLE	MEAN (SD)	RANGE	MEAN (SD)	RANGE
PC	.737 (.033)	.71/.78	1.051 (.018)	1.03/1.08
PS	.799 (.030)	.76/.84	.660 (.062)	.54/.72
DA	.638 (.025)	.62/.68	1.112 (.023)	1.07/1.14
DM	.638 (.025)	.62/.68	1.101 (.023)	1.08/1.14
DP	.638 (.025)	.62/.68	1.079 (.033)	1.04/1.14
BBL	.811 (.021)	.78/.84	1.000 (.000)	1.00/1.00
BBS	.811 (.022)	.78/.84	1.009 (.017)	1.00/1.04
BR	.907 (.021)	.86/.93	.695 (.047)	.62/.76
B	.864 (.011)	.85/.88	.647 (.028)	.61/.69
TBA	1.001 (.002)	1.00/1.00	.899 (.013)	.88/.91
TBO	1.001 (.002)	1.00/1.00	.868 (.036)	.81/.91
TBM	1.001 (.002)	1.00/1.00	.646 (.044)	.59/.70

IY :DISTANCE BETWEEN INSERTION (Y) AND
1. SHOULDER AXIS -TBA TBO TBM
2. ELBOW AXIS -PC PS DA DM DP BR
3. WRIST AXIS -BBS BBL
OY :DISTANCE BETWEEN ORIGIN (Y) AND
1. SHOULDER AXIS -BR B
2. ELBOW AXIS -PC PS DA DM DP BBL BBS TBA TBO TBM
BLI :ARM LINK LENGTH -PC PS DA DM DP
FOREARM LINK LENGTH -BBL BBS BR B TBA TBO TBM
BLO :ARM LINK LENGTH -PC PS DA DM DP BBL BBS BR B TBA TBO TBM

DISCUSSION

In addition to establishment a database of origins and insertions of twelve upper-extremity muscles, the present results provide a basis for reasonable prediction of origins and insertions of these muscles for individuals from easily measured link dimensions.

The ranges of x-coordinates and z-coordinates of origins and insertions of individual upper-extremity muscles, excluding the origins of PC and PS, were small enough to provide an objective basis for the determination of origin and insertion locations with acceptable accuracy. The x-coordinates of origins for PC and PS can be determined based on the biacromial diameter of individual subjects.

The y-coordinates from different upper extremities have larger variances, and are unable to be used directly. The results shown in Table 1 demonstrate that the SDs of the ratios of y-coordinate and link length for most of muscles studied are smaller than 4% of mean, except IY/BLI for PC(4.5%) and OY/BLO for PS(9.4%), BR(6.8%), B(4.3%), TBO(4.1%) and TBM(6.8%). The larger SDs of the ratios are perhaps due to the larger attachment areas of these muscles. Also, most of the ratios are within rather small ranges. Therefore, the ratio-means can be used to estimate the y-coordinates of insertion and origin of these twelve muscles based on the link lengths measured from subjects with an acceptable accuracy. The determination of the origin of PS may be better based on the sternal length than arm-link length of live subjects.

Using the above-mentioned ratios in combination with joint kinematic data and segmental link lengths should allow more accurate identification of muscle origin and insertion points. This information can then be used to calculate muscle length and moment arm changes during selected movement patterns. These values will be very useful for analysis of the individual muscle force and moment contribution during different upper-extremity motions, eq. wheelchair propulsion. If major architectural data of muscles as well as the kinetic data are made available, then the internal forces in the joints and muscles of the musculoskeletal system can be estimated much more accurately. (1,3,5).

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COMPLIANT THREE-AXIS FORCE SENSOR WITH DIRECT DIGITAL OUTPUT

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ABSTRACT

A compliant sensor designed to measure the normal and shear components of contact force was constructed and tested. The novel sensor element consisted of a 25 mm diameter rubber sphere protruding from a rigid close-fitting cube. Force applied to the protruding end of the sphere produces circular contact areas on the five sides of the cube. The diameter of the circular contact area was measured by micrometer and found to vary with the force perpendicular to the contact area by the formula: Diameter = 3.34 $(\text{Force})^{0.33}$. Forces acting perpendicular to the bottom surface could be predicted from the contact diameter with an error of approximately ±15%. This hysteresis error is caused by the viscoelastic properties of rubber. When normal and shear forces are applied simultaneously larger hysteresis errors are encountered due to side wall friction. These would have to be eliminated or reduced before the contact diameter becomes a useful predictor of applied shear and normal force.

INTRODUCTION AND BACKGROUND

Sensors that could measure contact forces between complex surfaces have applications in various medical and robotics areas. Contact forces between rigid or compliant surfaces, such as are produced between a shoe and the ground, between an prosthesis and the skin, and between the human or robotic fingers and a grasped object, are not easily characterized or measured. The magnitude and direction of these forces change along the x and y dimension of the contact surface. At any point along the surface the force is a vector described by a force component normal to the surface (the z component) and 2 components parallel to the surface (the x and y components). These x and y components are the friction or shear components of the force. Sensors for normal force measurement have been under development by numerous groups [1,2,3] including ourselves [4]. Extensive review of the literature revealed no descriptions of contact sensors that would be capable of measuring all three force components.

MATERIALS AND METHODS

Design Approach

During the last year we have been exploring the characteristics of a new tactile force sensor that transforms the normal force and the two shear forces of contact into digital information. The sensor element consists of a 25.4 mm diameter rubber sphere, 1/3 of which protrudes from an open box (Figure 1). The sphere is cast from an experimental conductive silicone rubber (Dow Corning X5-8027), with a nib extending from one end and a ball joint imbedded in the opposite end. The enclosure for the sensor is a acrylic cube sized slightly larger than the sphere diameter. The sphere is attached only at the center of the bottom surface of the cube via the rubber nib fitted into a hole. The contact forces to be measured, F_z and F_x, are applied to the exposed upper portion of the sphere as shown in figure 1. The reaction forces of the containment box result in a circular area of contact of the compliant rubber sphere with the five rigid surfaces of the box.

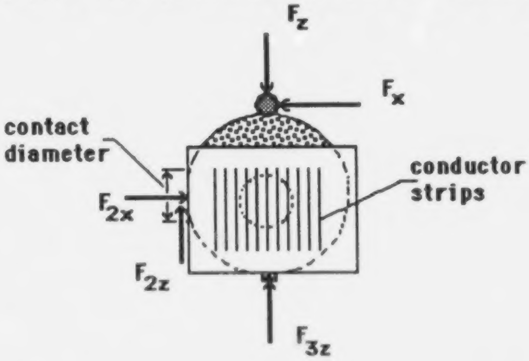

Figure 1. Conducting rubber force sensor in cube, showing contact diameter and various force components.

The variations of the diameter of the contact areas are transformed into electrical signals by sensing electrical contact of the conductive sphere with 16 conductors etched on each of the five surfaces of the containment box. The conductors are 0.5 mm in width with a center-to-center spacing of 1.5 mm.

Test Procedures

Initial tests were conducted to measure the relationship between applied force and the contact diameter for normal force (F_z only) and for a combinations of normal and one shear force ($F_z = F_x$). The applied force was measured with a calibrated load cell (Interface, Inc. MB-50). A rod was attached to the load cell by a hinge and, to the top of the rubber ball , via a ball joint. This insured that the applied force was directed along the axis of the rod. The contact diameter was measured by application of micrometer calipers to the circular contact area visible through the transparent walls of the cube.

RESULTS

Figure 2 shows the diameter of the contact area of the 25.4 mm rubber sphere as a function of various applied force components. The data points for increasing normal force, F_z and no shear force ($F_x = 0$) are shown as open squares. The average of this data is fit by a power curve given by equation 1, where the contact diameter, D, is in mm, and the force, F, is in Newtons.

$$D = 3.34 F_z^{0.33} \qquad (1)$$

The hysteresis, when there is no sidewall contact, is shown by the difference between the curve obtained with increasing force (open squares) and decreasing force (solid squares) in figure 1. The variation of contact diameter with the bottom and the side walls (diamonds) vs. the z and x components of force are shown as the lower curves (triangles and diamonds) in figure 2. The solid triangles represent the data for decreasing force on the bottom wall. These data show the increased hysteresis at the lower force levels in the presence of side wall contact.

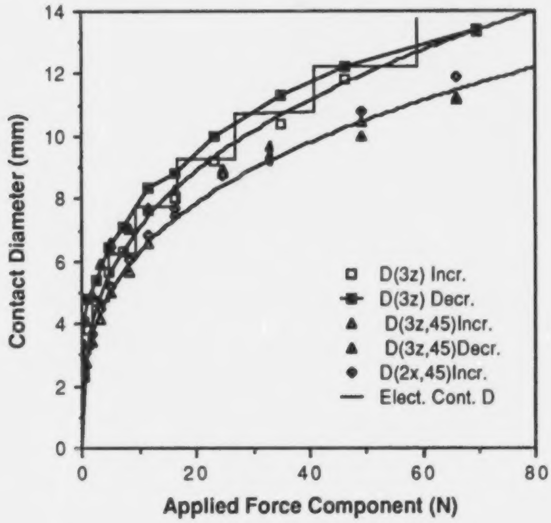

Figure 2. Diameter of rubber contact area vs. force components applied vertically and at 45 degrees showing hysteresis and friction errors.

The staircase function superimposed on the normal force data of figure 2. represents the calculated best resolution obtainable when the diameter is measured by detecting contact with conductors spaced 1.5 mm apart. The resolution of force measurement is reduced by the discontinuous nature of the diameter detection. The 1.5 mm spacing between conductors results in a predicted detectable increment that ranges from 0.4 Newtons at low force levels to 19 N at 50 Newtons force levels. The measured detectable force increments were a factor of 2 greater. This was attributed to the symmetric centering of the ball on the conductor grid which resulted in the ball contacting the conductors in even pairs, i.e.,. 2, 4 , 6 corresponding to diameters of 3, 6 , and 9 mm, rather than alternating contacts with 1.5 mm increments which would have been possible if the ball is placed off-center relative to the conductor grid.

DISCUSSIONS AND CONCLUSIONS

The diameter of the circular contact area of a rubber sphere varies approximately with the cube root of the normal force between the flat surface and the sphere. The nonelastic viscous effects of the rubber compression results in hysteresis where the difference in the diameters for increasing and decreasing force is typically 10%. This unpredictability in diameter results in an uncertainty in calculated force of approximately 30% due to the fact that force is proportional to the diameter cubed.

When the force applied to the top of the sphere has both a normal and shear component, the resultant reaction forces at the walls of the box have a normal component and a friction component. The normal force components can be calculated from the contact diameter, but the unmeasured wall friction components, which vary with the angle of the applied force, result in an indeterminate relationship between applied force and the normal reaction forces. These dry friction components produce an additional hysteresis effect whose magnitude is proportional to the friction coefficient. Lubrication of the side walls did reduce this hysteresis error, but the lubricant interfered with the electrical contact detection and also allowed excessive rotation of the sphere thereby leading to early failure of the nib attachment. These problems need to be overcome before this new type of tactile sensor can be usefully applied in robotics or prosthetics.

ACKNOWLEDGMENTS

This work was supported in part by a grant from the Center for Sensor Technology of the University of Utah.

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THE POTENTIAL OF MAGNETIC RESONANCE IMAGE FOR QUANTITATIVE GEOMETRIC MUSCLE INFORMATION

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INTRODUCTION

The geometric and mechanical information used in biomechanical models of the muscloskeltal system are usually estimated from a limited data based on cadaver measurements. Structural quantification from medical images is a field of considerable interest for scientists. X-ray CT and ultrasound have been used to estimate some geometric data of musculoskeletal system from live subjects (1, 2). Much less study has been done to evaluate the potential of Magnetic Resonance Imaging for quantifying geometric data.

The concept of MRI was first proposed by Lauterbur in 1973. Since then, the technique has undergone rapid development and has provided new and unique information without known health hazards. The excellent soft tissues contrast inherent in MRI allows subtle alternations in the soft tissues to be demostrated by MRI when they are not detectable using other imaging modalities. It has been used successfully in noninvasive evaluation of muscles, tendons and joint structures of hand, wrist, shoulder, knee, ankle, and foot (3). Most of MRI studies are qualitative evaluation of structures for diagonosis of disease and injury.

The purpose of the present study was to determine the potential of MRI to estimate quantitative parameters of muscles of the upper-extremity by comparing the MRI data and physical measurements from the same cadaver.

MATERIALS

Two upper extremities of a seventy-six old white male cadaver were used in this study. The cadaver was fixed for dissection purpose shortly after death, by infusion of 25% formaldehyde with dye, water softener, glycerin, and water into the carotid artery.

METHODS

A Siemens Magnetom 1 Tesla whole-body MRI system was used. Two upper extremities were imaged with different methods: 1) whole body T-1 weighted scanning was used on the right upper extremity with TR= .50, TE= 17, and 10 mm thickness sections obtained. 2) T-2 weighted imaging using surface coil was applied on the dearticulated left upper extremity with TR= 1.50, TE= 28, and 10 mm thickness sections obtained. Both upper extremities were imaged from the acromion to 10 cm below the elbow.

The images were read from magnetic tape and stored on a Winchester hard disk in a Masscomp computer system and were mapped from 12 bits per pixel to 8 bits per pixel to accomodate the available monitor. REGIS was used to trace the contours of biceps brachii, triceps brachii, and brachialis of each section by manual method with a mouse. Then, BSED was used to format REGIS output in order to calculate volumes. MOVIE.BYU was used to create 3D pictures.

After the magnetic imaging, the muscles of those two upper extremities were dissected from the cadaver and the volumes of muscles were measured by water displacement. The physical measured data and calculated data from MR images were then compared.

RESULTS

One image with muscle contours is presented in Figure 1. The muscle volume data are presented in Table 1.

Figure 1.

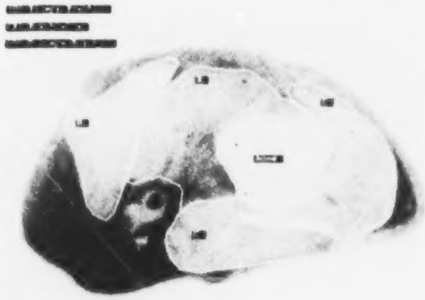


Table 1.

muscle	TRI		BB		B	
	MRI	P	MRI	P	MRI	P
Right	317	297	104	104	105	76
error(%)	6.7%		0%		38.2%	
Left	329	292	101	97	--	84
error(%)	11.2%		4.1%		---	

TRI : Triceps brachii
BB : Biceps brachii
B : Brachialis
MRI : Muscle volume calculated from MR images
P : Muscle volume from physical measurement
error : ((MRI - P) / P) * 100%

It can be seen from Table 1 that the error in determining muscle volumes from MRI Scan relative to the criterion method of water displacement ranged from 0% for the right BB to 38% for the right Brachialis.

DISCUSSION

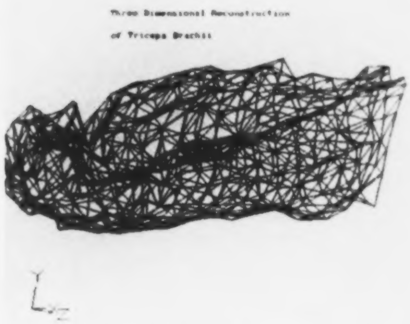
While these preliminary results ranged from good to unacceptable (in the case of volume estimation of the brachialis muscle) there is good reason to believe that the volumes of most, if not all, upper-extremity muscles can be determined with less than 5% error. This optimism is based on several potential improvements, including higher resolution through the use of the surface coil in contrast to the whole-body scan used in the present instance, use of live subjects with better alignment of muscles along principal axis of the magnetic field, taking thinner sections to increase resolution, and by adjustment to achieve optimal contrast.

There is considerable potential with respect to the latter consideration as the MRI instrumentation was configured for typical clinical scans rather than optimized for discrimination along fascial planes.

Work in progress has resulted in much better images than those used in the present study.

The three dimensional reconstruction of the triceps brachii presented in Figure 2 demonstrates the potential of the serial MR imaging and image processing techniques for quantifying other valuable geometric data.

Figure 2.
Three Dimensional Reconstruction
of the Triceps Brachii



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ACKNOIWLEDGMENT

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THE VALIDITY AND RELIABILITY OF THE B200 ISOSTATION: A TRIAXIAL SYSTEM FOR FUNCTIONAL ASSESSMENT OF THE TRUNK.

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INTRODUCTION:

Quantification of the strength and endurance of trunk muscles and measurements of the trunk's range of motion and pattern of movement have been important elements of functional assessment tests of the trunk. Kroemer classifies the strength measurements into three categories; isometric, isokinetic and isoinertial (1). Although isometric tests have been used extensively, no commerical system has been available to simultaneously measure strength, and range of motion triaxially. The primary purpose of this study was to establish validity and reliability of the B200 Isostation. The second purpose was to study the reproducibility of the isometric strength measured in sagittal, frontal, and coronal planes.

MATERIAL AND METHOD

The B200 Isostation from Isotechnologies, Inc. is a computer controlled triaxial system that simultaneously measures trunk's angular position, velocities and torques in all three planes; flexion/extension, lateral bending and axial rotation. The B200 Isostation system was loaded by calibrated weights from a known distance from each axis of B200 machine sequentially. The R-square for the linear regression analysis between the weights loaded off axis and torques registered by the B200 system for each axes were computed. The R-square for linear regression between the measured angles from goniometer aligned with each axis and angle registered by the B200 system for all three axes were computed. All measurements were duplicated.

Twenty normal male subjects with no history of back pain for the last six months participated in second part of this study. The mean (SD) age, weight and height of these subjects was 28(6 years) 1.7 (.6)m, 74 (12)kg respectively. The subjects were positioned in their upright neutral position with flexion/extension axis of the B200 aligned with their L5-S1 level. Maximum isometric exertions were sustained for 5 seconds followed by one minute rest period. Maximum exertions were produced in all directions and three trials were repeated in each direction. The Pearson correlation between the three tirals were computed. The Statistical Package for Social Sciences (SPSSx) were used for data analysis.

RESULTS:

The regression analysis yielded linear equations with strong predictability power. The R-square computed for both torque and angle ranged from .985 to 1 (p .001). The reproducibility was also excellent. The Pearson correlations between the three trials ranged from .88 to .96 in the saggital plane tests (p .001). The complete data can be obtained from the authors upon request.

CONCLUSION

The B200 Isostation is a valid instrument for measurement of strength and range of motion of trunk and isometric performances of the normal subjects in this study were highly reproducible over the three trials.

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A CENTER OF PRESSURE INSOLE USING FORCE SENSING RESISTORS

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ABSTRACT

Force sensing resistors have been utilized to give real-time center of pressure information during the stance phase of gait. Four sensors placed on a foam rubber insole measure the force under the bony prominences of the foot. The center of pressure is then determined geometrically. Preliminary comparative experiments suggest that the estimated trajectory of the center of pressure obtained by the insole follows a similar path as that of the force plate center of pressure.

INTRODUCTION

In the control of electrically stimulated walking, it is important to have lightweight, cosmetic and accurate sensors for measuring a number of gait variables. A device which measures force at the high pressure points of the foot could provide valuable information related to gait such as heel contact, toe-off, weight acceptance and the spatial tracking of center of pressure. Information about the center of pressure can be used in conjunction with other sensors to determine if a person is leaning too far forward or backward during standing. For the control of gait, center of pressure information can be used to trigger muscle stimulation based on event detection.

This work focuses on the development of a mobile device for measuring center of pressure in real time. It has the potential of being completely portable, although it is currently being run from a breadboard via cables. Moreover, it is easily assembled, quite inexpensive, and requires only a low-voltage DC power supply and minimal signal processing. The general approach follows the work of Chizeck [1], in which sensors are mounted on an insole below the bony prominences of the foot. Our insole differs in the method of transduction, which in this case is the force sensing resistor (FSR) element [Interlink Electronics]. FSR's are thick-film, screen printed devices, the resistance of which decreases as more force is applied. This paper outlines the preliminary results of experiments using FSR's to measure the center of pressure on the sole of the foot during walking.

METHODS AND RESULTS

Evaluation of the FSR's

The FSR's were calibrated on the foam insole. The output in the region of interest (0 to 30 lbs) was found to be linear ($r = -0.9978$).

Drift was measured with the FSR's mounted on the insole, and was found to increase with increasing force. After 10 minutes of constant force application, the output voltage had decreased by 17% with 25 lbs of force, but only 4.5% with 0.75 lbs applied. For short periods of time (0 to 20 seconds) drift was constant (about 2%) over the whole range of forces. Drift could account for the hysteresis seen in these sensors. Average hysteresis was found to be 6.4% (compared to 7% for Maalej, et al [2]).

Evaluation of the Insole

Four sensors were placed on a foam rubber insole at fixed locations under the calcaneus, hallucis, medial metatarsal and lateral metatarsal. The coordinates of the sensors were defined to be (0,0), (15,81), (17,57), and (0,60) respectively. To compute the x- and y-coordinates of center of pressure, the following equations were used:

$$COPx = \sum_{i=1}^{4} F_i x_i / \sum_{i=1}^{4} F_i$$

$$COPy = \sum_{i=1}^{4} F_i y_i / \sum_{i=1}^{4} F_i$$

where F_i = Force on i^{th} sensor
x_i = x-coordinate of i^{th} sensor
y_i = y-coordinate of i^{th} sensor

Trials were performed for single steps across a force plate. The results of one trial are shown in Figure 1. Spatially, the insole center of pressure follows that of the force plate fairly well, although the latter is constrained to be within the geometry of the sensor locations. The time course of the x and y coordinates of center of pressure for the same step are given in Figures 2 and 3 respectively.

DISCUSSION

The FSR insole that we have developed has its strength in its portability, its real-time application, its durability and low cost. It is evident that the spatial tracking of the insole is limited by the geometric placement of the sensors (i.e., center of pressure is "clipped" at the sensor locations). Despite this, the insole gives information about the center of pressure which is adequate for simple control procedures (for instance, determining "too far forward" or "too far backward"). This could be improved by the addition of more sensors.

Current work with this insole includes its use as a footswitch for triggering stimulation patterns during functional electrical stimulation (FES) walking. Progress is underway to utilize center of pressure information in control schemes for both FES walking and stance.

ACKNOWLEDGMENTS

This work has been supported by the Rehabilitation Research and Development Service of the Veterans Administration.

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Figure 1. Center of pressure trajectories for the FSR insole (solid) and force plate (dotted)

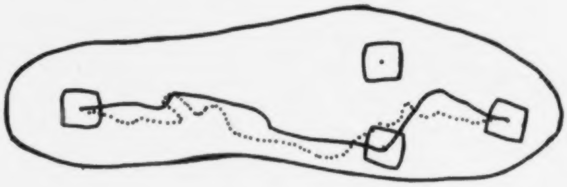


Figure 2. Time course of the x-coordinate of center of pressure. Distance given in inches x 10.

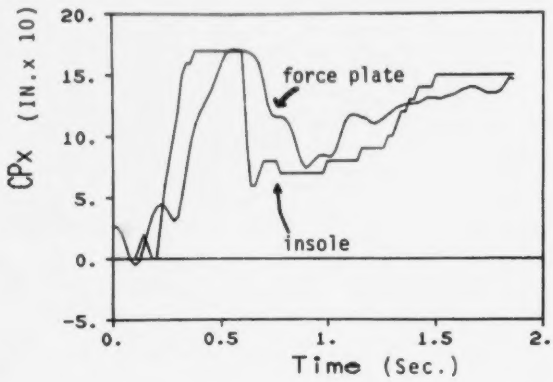
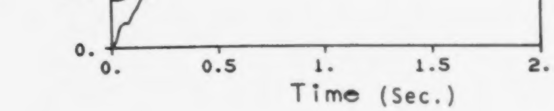


Figure 3. Time course of the y-coordinate of center of pressure. Top trace is the insole, bottom trace is the force plate.



PARALLEL BARS FOR THREE DIMENSIONAL FORCE MEASUREMENT

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INTRODUCTION

This paper describes a parallel bar force measurement system which can be used to measure applied forces in three dimensions. It is designed for a 0-100 kg force measurement range. This parallel bar can be used to measure the hand support load of paraplegic subjects during stance and gait training.

METHOD

Pin joint connectors, instead of rigid ones, were used between horizontal bars and their supports, so that the bending moment along the y-axis could be eliminated and the horizontal bar angle easily adjusted (Figure 1). Twelve CEA-13-032UW-120 miniature strain gauges (M-M measurement Group, Inc., Raleigh, North Carolina) were mounted on modified supports to measure three components of the force exerted on the bars by the subject. Each support had three Wheatstone bridges to detect the gauge's small resistance change.

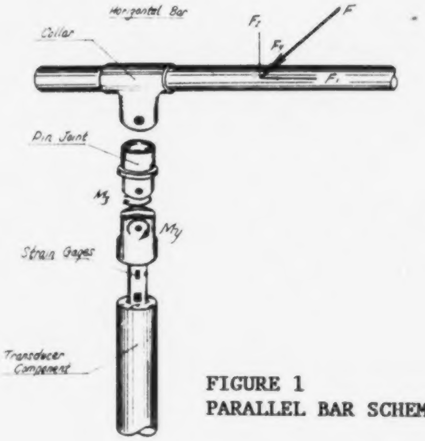
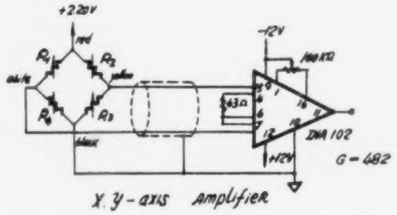

Horizontal Bar
Collar
F_z
F
F_y
F_x
Pin Joint
M_z
M_y
Strain Gages
Transducer Component

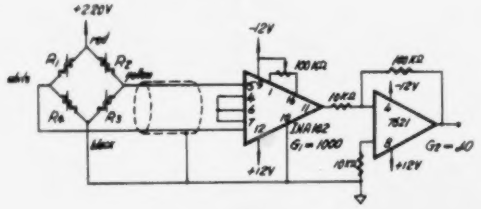
FIGURE 1
PARALLEL BAR SCHEMATIC

Hardware

Twelve standard foil strain gauges were used to measure the three dimensional forces F_x, F_y, F_z. When the gauge was attached to the structure, which was loaded by some force, it deformed by the same amount as the structure. This resulted in a change of resistance. We used four strain gauges for each axis in a Wheatstone bridge. Then an INA102G instrumentation amplifier (Burr-Brown, Corp., Tucson, Arizona) was used to amplify the low level differential signal from the Wheatstone bridge. The z-axis signal was amplified more due to different sensitivities (Figure 2).


+2.20V
red
R_1
R_2
white
yellow
R_4
R_3
black
-12V
100KΩ
43Ω
INA 102
+12V
G = 482

X. Y-axis Amplifier


+2.20V
red
R_1
R_2
white
yellow
R_4
R_3
black
-12V
100KΩ
INA102
G_1 = 1000
+12V
10KΩ
100KΩ
-12V
7521
G_2 = 40
+12V
10KΩ

Z-Axis Amplifier

FIGURE 2 WHEATSTONE BRIDGE AND AMPLIFIER

Three components of a force on the parallel bars are:

$$F_x = (EI/Sg\ Vin\ CL)\ V_{ox}$$
$$F_y = (EI/Sg\ Vin\ CL)\ V_{oy}$$
$$F_z = (2EA/Sg\ Vin\ )\ V_{oz}$$

where:

E is the modulus of elasticity (Young's Modulus)
I is the moment of inertia
Sg is the strain gauge factor (2.11 for CEA)
C is the radius of the support
L is the strain gauge's distance from the pin joint
A is the cross sectional area
Vin is the bridge excitation level

For each parallel bar we have:

$$F_{x1} = (EI/Sg\ Vin\ CL)\ (V_{ox1} + V_{ox4})$$
$$F_{x2} = (EI/Sg\ Vin\ CL)\ (V_{ox2} + V_{ox3})$$
$$F_{y1} = (EI/Sg\ Vin\ CL)\ (V_{oy1} + V_{oy4})$$
$$F_{y2} = (EI/Sg\ Vin\ CL)\ (V_{oy2} + V_{oy3})$$
$$F_{z1} = (2EA/Sg\ Vin)\ (V_{oz1} + V_{oz4})$$
$$F_{z2} = (2EA/Sg\ Vin)\ (V_{oz2} + V_{oz3})$$

For the gauge with grid area = 0.81mm x 1.52mm = 1.23 mm^2 and heat sink condition 2-5 watts/in^2 (heavy aluminum, high accuracy), we chose the strain gauge bridge excitation voltage of 2.20V.

Calibration

The single bar is calibrated by keeping it level, and putting different weights on each axis (Figure 3). Next, bar calibration forces F_x, F_y, F_z are applied at different positions by putting different weights on the parallel bar (Figure 4).

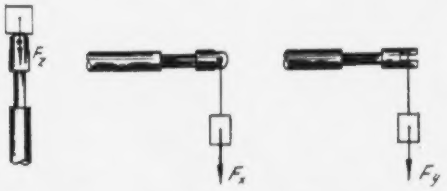


FIGURE 3 SINGLE BAR CALIBRATION

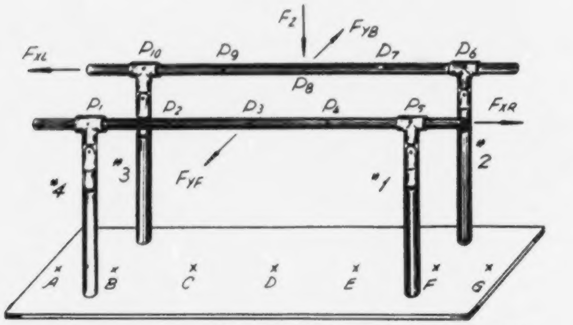


FIGURE 4 NOTATION OF THE PARALLEL BAR

RESULTS

After calibration, the calibration chart or equations were generated using linear regression analysis [2]. The parameters A and B in the equation:

(output voltage) = A + B(input force)

were found for each applied force on each upright from the calibration data and charts. We found that the result was symmetric and highly linear. For the single bar, the slope was about 25 mV/lb. For the parallel bar, the z-axis and x-axis slope was about 21 mV/lb and for the y-axis it was about 44 mv/lb (Figures 5, 6).

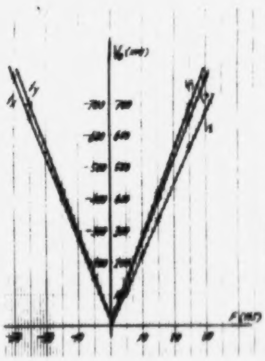


FIGURE 5
SINGLE BAR
CALIBRATION CHART

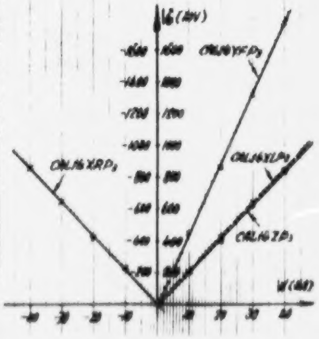


FIGURE 6
PARALLEL BAR
CALIBRATION CHART

DISCUSSION AND CONCLUSIONS

This parallel bar, 12-channel force measurement system, has been designed [1], fabricated and calibrated. Calibration charts showed good linearity and symmetry, even though there was a maximum of 4% crosstalk among the three axes. In order to get good results, we found the following points very important.

1) The 12 strain gauges must be accurately mounted, because the crosstalk is mainly caused by mounting error.
2) Appropriate excitation levels must be selected and an accurate DC power supply used.
3) Shielded cable should be used, as the gauges' signals are very weak.

ACKNOWLEDGEMENTS

This work was funded by the Rehabilitation Research and Development Service of the Veterans Administration, and was also supported by the China State Ship-building Company.

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DEVELOPMENT OF A BIOMEDICAL DATA LOGGER FOR LONG TERM PHYSIOLOGICAL MONITORING

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INTRODUCTION

A versatile data recorder has been developed to allow clinicians to accurately record numerous patient activities over extended periods. The Biomedical Data Logger is designed to be an improved alternative to the diary-based method of recording daily activities. The logger includes an internal clock to provide a temporal record of the day's events. It is compact (5"X5"x1 1/2") and lightweight (< 1.5 lbs.) so it won't hamper movement or cause discomfort.

The versatility of the logger comes from the non-dedicated input system that can be easily customized to each application by choosing a variety of transducers. For instance, a Low Back Pain patient can be monitored to see how often his/her back is flexed throughout the day or a step indicator can be used to study the gait of an AK amputee after being fitted with a new prosthesis. By providing several separate inputs, numerous kinds of events or situations can be recorded for analysis.

The Biomedical Data Logger system is designed for use by clinicians. The accompanying software, used to program the recorder, is completely menu-driven and self-explanatory.

SYSTEM DESCRIPTION

Hardware. The central component of the Biomedical Data Logger is an 80C31BH CHMOS 8-bit CPU with RAM and I/O. The CPU contains 128K X 8 read/write data memory, 32 I/O lines, two 16-bit timers/counters, a serial I/O port and on-chip oscillator and clock circuits. These CPU capabilities are augmented by an additional 64K x 8 bits of RAM for read/write data memory; a 3.58 MHz crystal to provide the clock frequency for the system; two line driver/receiver chips to provide 8 counter and 8 parallel port inputs; two A/D conversion channels and a dual RS-232 receiver/transmitter for communication with a host computer. Program instructions are contained in a CMOS EPROM with 8K X 8 bits of memory. The instrument is constructed on a printed circuit board and is driven by dual 5.4 V mercury batteries. A simplified diagram of the data logger is shown in Figure 1.

Data Input Sensors. The microprocessor unit is capable of recording information from three sources, counters, status bits, and A/D conversion. These inputs can record and identify a wide range of body signals or parameters depending on the terminal transducer used.

Eight counter inputs are available to record input counts over a specified integration period. Counters can be used to quantify any physiological signal or event. Heart rate, respiration rate, and step count are a few examples of quantifiable events which can use counter inputs. Counter inputs may require some external signal conditioning to be easily recognized by the logger. For instance, EKG activity is filtered so the logger simply records a beat whenever the QRS complex is recognized.

Seven status bits are available from the parallel port of the microprocessor. These bits will return status information for any event, condition, or situation that can be represented by two distinct states (high/low, on/off). Status bit applications include body position (sit/stand), head position (erect/askew) and pressure reliefs (up/down).

The two A/D inputs are available to sample any biomedical signal that can use the available 2.5 V reference and a minimum sampling frequency of 0.02 secs. Typical signals sampled by the A/D's include EMG activity and seat surface temperature.

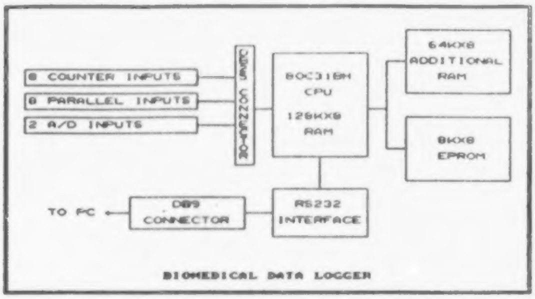

Fig_1. Simplified Hardware Layout

Software. The system software includes two separate programs with the microprocessor instructions housed in the EPROM chips and the controlling software run using MS-DOS with the host PC.

The PC program acts as communication and data manipulation software to allow the clinician to set the recording parameters, create data files, and display data via text or graphics.

Each recording session begins with the initialization of the data logger. Sampling is done and data is recorded in multiples of .02 secs which represents the fastest available sampling frequency. The clinician sets the sampling algorithm by choosing the Basic Timing Interval (BTI) and sampling parameters for the neccesary data inputs. The BTI can range from .02 to 1.98 seconds and sets the mimimun integration time for each input. In addition, each counter is initialized with a counter timing interval (CTI) and a holdoff counter (HO) which are both multiples of the BTI. The CTI sets the time interval over which data is collected and stored as a data point. The HO sets a latency period during which two counts cannot be processed. For example, if steps are being monitored and the integration period (Int P= BTI * CTI) is set at 10 secs and the latency period (Lat P=BTI * HO) is set at 0.4 secs then steps would be totaled every ten seconds but two steps could not be registered within 0.4 seconds of each other. The data file would contain 10 second intervals of step counts collected over the entire recording session.

Parallel input data is collected as Status bits and is initialized with a sampling interval that returns the status at the end of the interval. The two A/D inputs require a sampling interval which is also a multiple of the BTI.

The other functions of the PC software are to receive data from the logger, create and dump data into a file, and extract the data for printing and/or plotting. A sample of plotted data is shown in Fig. 2. Data units, time units and axis labels and divisions can all be easily changed for each set of data. In addition, the maximum and mimimum data counts and the elapsed recording time are displayed.

The program instructions for the data logger consist of a interrupt-based sampling algorithm that scrolls through all the initialized data inputs every .02 secs and records data points at the end of each respective integration period. Data is stored sequentially in RAM. The data can be dumped to a MS-DOS file in the host PC where it can be selectively extracted and displayed.

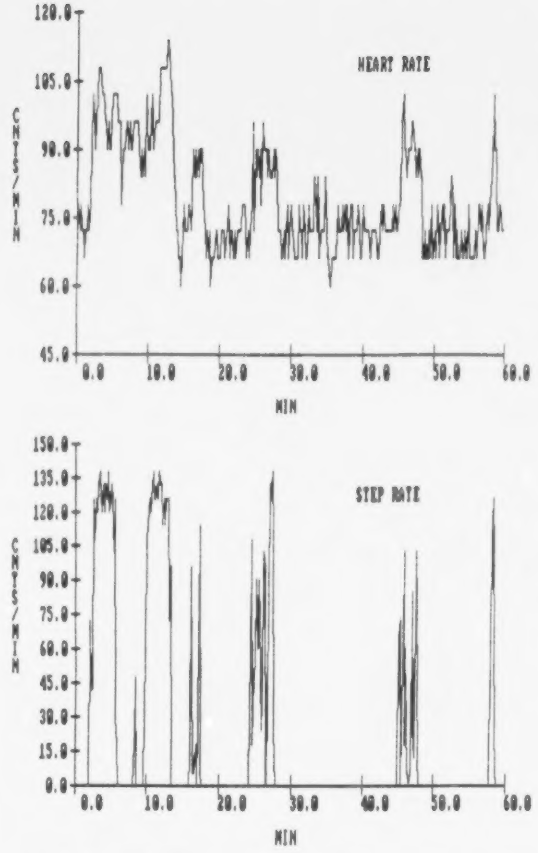

Fig_2. One_hour of plotted heart rate and step count data.

ACKNOWLEDGEMENT

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AN EVALUATION TOOL FOR SWITCH SELECTION

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ABSTRACT

The device described provides information on the subject's target size and force generation. Such information can be used to find the best match between user and available switch.

INTRODUCTION

The best match between user and the type of switch needed to access technology is often dependent on the professional's supply of switches on hand. Frequently, the determination of the most suitable switch is by trial and error. Professionals without a variety of switches on hand have difficulty catalogue shopping. Many catalogues provide valuable technical information on each switch, including the size of forces needed to generate activation, and the size of the actuator. Such information is not currently used by professionals, because they do not have a method of evaluating an individual's target size or force generation.

METHOD AND MATERIALS

The device consists of two components: a target size indicator and a strain gauge force transducer to measure force generation. The touch switch has ten copper rings in concentric circles, configured on a printed circuit board. Ten rings are spaced two-tenths of an inch apart to create a target size from dead center to a diameter of three inches, with an LED light attached to each of the rings. A thin rubber conductive sheet is spread slightly above the board. When the rubber sheet is depressed, the underlying ring is contacted, completing the circuit and causing the corresponding light to go on. Quickly, an evaluator can see the client's target range depending on the number of lights lit.

The force being applied to the switch is measured by a strain gauge force transducer in a range from zero to five pounds, with one thousand increments within the range. Signal conditioning is achieved by using the Wheatstone bridge configuration for the force transducer as an input to a Burr-Brown 102 instrumentation amplifier with switch adjustable gain. A sample and hold circuit is used to capture the peak force applied by the subject when contacting the target plate. The peak force is then displayed using a digital panel meter.

An individual is asked to activate the device with whatever consistent movement pattern has been selected. The device is designed to be useful at any anatomical location where the subject has the potential for consistent, reproducible movement. Mounting the device allows the evaluator to setup the subject, step back and objectively evaluate the potential of a particular anatomical site as a switch site.

CONCLUSION

With the information on target size and force generation, a professional is better equipped to make a recommendation for a specific switch. An individual can then use the recommended switch with one of the many software training programs currently available.

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A DEVICE TO MEASURE UTILIZATION OF ASSISTIVE DEVICES

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INTRODUCTION

"The use of Assistive Devices has expanded rapidly during the past decade and provincial governments in Canada and both national and state governments in other jurisdictions have developed programs to fund the cost of these devices and/or to directly supply such devices. In addition third party payment by private health insurance companies has become wide-spread."[1]

Indeed over thirty million dollars is spent annually by the Ontario Government through its Assistive Devices Program which provides financial assistance to end users requiring these devices. "There has however, been very little research on the utilization of devices and no reported research on the utilization of devices supplied through a province-wide program."[1]

THE NEED

There exists a glaring need to determine the efficacy of this technology - to measure, objectively, just what it means, in terms of outcomes, to use these devices and systems. Why, then, has this not been done? There are tools available to measure a variety of outcomes relevant to using these devices. The following example reveals a fundamental problem. Suppose we hypothesized that the use of a voice output communication aid for a non-verbal clientele would result in an increase in quality of life (QOL). Using available psychology tools, we could, say, establish a QOL baseline for each subject prior to applying this technology. Then, perhaps at six month intervals, measure QOL again and compare these results with previous ones. Hopefully, we would see a trend of positive shifts in the QOL index. So far, so good. We would now need to establish a correlation between this trend in QOL and utilization of the device. One cannot just assume that providing the device made the difference. Perhaps it was other factors or events that caused the change to occur. Attempts to acquire utilization data to date have usually consisted of applying a questionnaire to the subjects and/or family members, etc. Even if the questionnaire is of excellent design the results are based on subjective responses and, at best, compliance is suspect. Herein lies the heart of the problem - how to objectively measure utilization of the device over a period of time.

A SOLUTION

The Technology Access Clinic intends to evaluate the effects of applying assistive devices to various populations and settings. This long range goal has the development of a module that can measure the utilization of electronic aids as its first objective. A device developed at the Hugh MacMillan Medical Centre was reviewed and found to be capable of accumulating the occurrences of two independent events and the combined accumulative durations of these events [2]. This is an excellent example of the kind of technology required to measure utilization but it could not acquire sufficiently detailed data for our purposes since it was only capable of capturing gross numbers.

Design criteria
The required module, it was felt, should meet or exceed the following list of capabilities:

Basic function - able to count occurrences of two or three independent events.

Data capacity - capable of storing these accumulated totals on a daily basis for a minimum of two to three months.

Data retrieval - allow easy download, display, and clearing of the acquired data at periodic intervals

Power requirements - self-powered to the extent that it can collect and retain data between downloads even if the host power supply fails.

Size - sufficiently small enough to allow installation inside a host device without undue difficulty.

Flexibility - applicable to a wide range of electronic aids.

Recycable hardware - the device should be capable of being re-programmed to the extent that it can be re-used in more than one study. That is, the hardware will not need to change significantly from study to study.

Transparency - the host device's function must remain unchanged such that the data collection process is completely transparent to the user.

APPLICATIONS

A typical application might involve installation into a group of voice output communication aids. They would, perhaps, monitor and count the numbers of times that the device "speaks" and the number of times that the printer is activated in a day. Daily totals for both events would be stored in a memory. The accumulation of daily totals would be downloaded to a microcomputer every few months whereupon the unit would be reset, cleared of data, and sent out again to continue data collection. The downloaded data would eventually be analyzed and made available in ways that allow for ease of interpretation and comparison with other related data.

Further details on the project and suggestions for future research using the module will be presented.

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TELECOMMUNICATION DEVICES FOR THE DEAF: HOW DO USERS EVALUATE THESE PRODUCTS?

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ABSTRACT

This paper discusses the factors deaf and hearing people use to judge the acceptability of Telecommunication Devices for the Deaf (TDDs). Recommendations for improvements in the implementation of the factors are noted. (The term "deaf" in this report is used to describe those people who have insufficient hearing to be able to identify speech through hearing alone). This research programme was conducted at Bell-Northern Research and supported by funds from Bell Canada.

METHOD

Products. Several (TDDs) were chosen for evaluation based on the range of features and functions they provide. The devices chosen ranged from those which are acoustically coupled to the telephone handset to advanced integrated devices providing telephony and word processing capability. The products were divided into three groups: basic, intermediate and advanced.

Subjects. Participants in the investigation were drawn from both the deaf and hearing populations within the French and English communities of Quebec and Ontario. All participants had prior experience with TDDs. A distinction was made between TDD "users" and "choosers", the latter being individuals who may not use their TDDs frequently, but who work in positions where they are required to make product recommendations.Participants were assigned to particular groups on the basis of their experience with the functionality provided by the products. 21 participants reviewed the basic products, 24 participants reviewed the intermediate products and 14 participants reviewed the advanced products. Few of the participants reviewed more than one group of products.

Evaluation Methods. 61 TDD attributes were identified for evaluation. The attributes were identified through discussion with TDD users and choosers as well as on the basis of professional knowledge about TDDs. The attributes were classified under the physical category headings:

Documentation, Industrial Design, Keyboard, Printer, Screen

Participants were required to rate between 52 and 61 TDD attributes on a four point acceptability scale: not acceptable, marginal, acceptable and exceptional. The range of attributes was reduced for the basic devices since these products did not have printers. The "not acceptable" rating was assigned to attributes which participants thought would be rejected in the marketplace. The "marginal" rating was assigned to attributes that participants thought would provoke complaint but that would not cause the product to be rejected in the marketplace. The "acceptable" rating was assigned to attributes that participants considered were typical of those encountered in the marketplace (i.e. nothing special). The "exceptional" rating was assigned to attributes that participants considered were market leaders.Each Evaluation session was preceded by a familiarization period. At the completion of the familiarization period, the formal evaluation began.

RESULTS

Factor Identification. Cluster analysis of participants' acceptability ratings revealed seven relatively independent underlying functional factors on which people rate TDDs:

call status, **congeniality**
delayed message review, **functionality,**
immediate message review **message entry,**
portability.

Documentation should be considered an eighth factor. Acceptability ratings for Documentation were not included in the Cluster Analysis because French texts were not available.

Each factor incorporates several TDD attributes which cross the physical categories of the TDD. For example, screen attributes may be grouped with printer attributes.

Factor Implementation

Call Status. This factor refers to attributes associated with accessing, holding and disengaging a line. In common with other telephone users, TDD users need to know what is happening on the line while placing a call. Whereas hearing people can monitor the line auditorily and do so even when using a TDD in acoustic coupling mode, deaf users currently must rely on the call status lights. Users have problems interpreting the call status lights, e.g., busy vs fast busy. The problem is magnified by interference introduced by ambient noise in acoustic coupling mode.. Text prompts, instead of lights, would facilitate the accurate interpretation of call status signals and would improve the acceptability of the products.

Congeniality. This factor refers to attributes associated with how agreeable the TDD is to use. Products seen to be congenial have a compact appearance when everything is packed away inside the carrying case. Non-slip shoulder straps are highly regarded. Congenial TDDs are rated easy to set up for acoustic coupling. That is, the telephone handset fits snuggly into the acoustic coupler but can be removed without lifting the TDD with it. The A.C. adaptor has no special storage requirements and is easy to remove from the carrying case and install. Text layout is also an attribute influencing congeniality. Wider printers are more congenial than narrower printers. The data suggest that the desirable minimum paper width is 40 characters. Finally to be congenial the battery should reliably hold its charge for longer than one hour.

Delayed Message Review. This factor is dominated by printer attributes. TDD users seem to have somewhat different uses for the screen and printer. While letters are being entered or received the screen is used for instantaneous message review whereas the printed version is available for a somewhat delayed review capability. The delay can be quite short for example, when users want to review what they have just written and part of their last transmission has already left the screen and is being printed. Alternatively, the delay can be long when users are reviewing a call after it has been completed. The facility with which TDD users can review text which has left the screen is strongly dependent on the width of the printer buffer. Ideally the print buffer should be no longer than the width of the screen . A minimum printer width for acceptable performance is 40 characters.

TDDs that differentiate between sender and receiver on the hard copy are more highly valued than those that do not.

Printer noise, keyboard sound and keyboard feel are also attributes in this factor. We believe that printer noise and keyboard sound are used by hearing people as feedback indicating that an action has taken place in response to a key press and that information is available for review. Deaf users appear to use keyboard feel and printer speed attributes as similar feedback indicators.

Functionality. This factor refers to attributes associated with accessing the features of the TDD. The features include telephony access, call set-up and user controllable memory. Products received good ratings for grouping keys by functions for example, dial, hang up, call pick up and last number redial, would have unique keys physically separated from the main body of the keyboard. Screen prompts confirming key actions (e.g. "Message Saved") are also highly valued. That is, no product is rated acceptable without appropriate screen prompts.

As the functionality of products increases, manufacturers should include escape sequences to permit users to exit features entered in error and return to the point of entry. This is a common problem among current TDDs.

Immediate Message Review. In contrast to the delayed message review factor above, this factor was dominated by screen attributes. That is, ratings for letter size, screen contrast, letter spacing, screen legibility in dim and bright lighting, and screen legibility from a wide viewing cone were all correlated. TDDs with gas discharge tube displays are more desirable than LCD displays because they can be viewed under more varied lighting conditions (including at night) and from wider angles, thus allowing more than one viewer to comfortably participate in a conversation. A minimum character width to achieve a totally acceptable performance rating was greater than 32 characters.

Message Entry. Message Entry is a multi-modal activity. That is, TDD users enter text via the keyboard, but instantaneous confirmation of text entry is achieved by looking at the screen and the printer. Consequently, keyboard, screen, and printer attributes contribute to the Message Entry factor. However, keyboard attributes dominate this factor. There is no uniform keyboard arrrangement in TDDs today. Three keyboard arrangements were identified in this investigation:

modified 4-row TTY keyboard,
QWERTY keyboard,
QWERTY keyboard superimposed on the modified 4-row TTY keyboard.

This diversity of keyboard arrangements results from manufacturers attempts to support both ASCII and BAUDOT transmission codes within one TDD. Figure 1. indicates the user problems encountered when using the different keyboard arrangements. There is a need for an industry standard for TDD keyboards. The establishment of this standard would be simplified greatly if only one transmission code was involved.

TRANSMISSION CODES	KEYBOARD ARRANGEMENTS		
	TTY	QWERTY	QWERTY & TTY
BAUDOT	All keys transmit in Baudot	Some characters do not transmit in Baudot	■
BAUDOT & ASCII	The TTY keyboard does not provide a complete 64 character ASCII set	Full ASCII set but no indication which keys don't transmit in BAUDOT	No differentiation between ASCII and TTY keys

In addition, TDDs with standard typewriter ergonomics (e.g. force, key travel etc.) are more acceptable to users than those not observing these standards.

Screen font quality was also a focus of concern. The majority of TDDs available today use gas plazma screens and some characters are difficult to discriminate (e.g. 5 for S and 7 ? and 2).

Portability. Size, weight and appearance all influence users concept of portability. Small, compact products are more suited to daily transportation than the larger desk-top versions. For deaf people who use sign language, it is preferable to include a carrying case with a shoulder strap so that users' hands are free . Larger desk-top units may also need to be moved from time to time. Consequently, the acoustic coupler and printer should attach firmly to the base unit so that unit can be transported in one piece.

Documentation. Product documentation should provide users with instructions based on what they want to do with their TDDs. Sections should be organized with the most basic, frequently performed tasks at the beginning. In addition, pictures should accompany text and provide users with an accurate pictorial representation of keystrokes. Chord keying (keying requiring the activation of more than one key) was an issue that was not well addressed in any of the documentation accompanying the products evaluated. TDD users who are unfamiliar with the concept of activating functions by pushing a control key in addition to a second key often did not press the control key first. They usually attempted to push both keys simultaneously which often resulted in the function key preceding the control key.

Technical language should be avoided. Issues related to computer access; enrollment procedures and transmission codes for example, should be in a separate section and referenced in the table of contents and index.

If manufacturers need to describe the operation of a family of products within a single instruction book the instructions for each family unit should be clearly delineated and grouped together.

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A Recumbent Cycle Ergometer for Disabled Individuals

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Introduction

Standard bicycle ergometers used for determining aerobic exercise capacity may not always be appropriate with certain clinical populations. Individuals who are ataxic due to disorders such as multiple sclerosis, cerebral palsy, traumatic brain injury, etc. might experience difficulty maintaining adequate balance to perform an upright bicycle test. Although these patients frequently have some lower-limb function, they typically use arm exercise for stress testing and training. Therefore the purpose of this project was to develop a leg ergometer that would minimize the problems of balance and posture, while still providing results similar to upright cycling. Such a device would have applications for both testing and training.

Methods

Development of the recumbent bicycle consisted of modifying a standard upright Monark bicycle ergometer. The results are illustrated in Figure 1. Initially, the Monark was mounted on a platform in a vertical position to which a stabilizing frame was welded. The vertical angle selected allowed the crank and pedal to be positioned to maintain a horizontal leg/hip position. A 12" extension of the bike frame was included to allow use of the ergometer in shoulder-height water without the threat of wetting to the flywheel and friction belt. Following these structural changes the bike and frame were secured to the platform. A wooden seat with foam cushions which is adjustable in an antero-posterior motion provides a hip and knee angle similar to upright cycling. Belting of the hip region stabilizes the trunk to further standardize body position. Velcro straps assure uniformity of foot placement and prevent vertical foot slippage. To validate this recumbent ergometer (R-ERG), a comparison was made to a standard upright Monark bicycle ergometer (BERG) at selected power output (PO) levels.

Nine healthy, moderately active volunteers participated in this study (6 males, 3 females). Mean (± SD) age, height, and mass were 27 ± 7.0 yr, 175 ± 8.1 cm, and 70 ± 14.8 kg, respectively. Following a 5-min rest period, an incremental, continuous test of 5-min submaximal stages of 30, 60, and 90 W was performed on both ergometers. A fourth level of work was performed during which each subject worked at a specific PO that approached his/her maximal aerobic power (VO_2 max). Metabolic data, ECG, BP, and Category-Ratio Rating of Perceived Exertion (2) were recorded throughout all tests.

A 2 X 5 factorial ANOVA design with a post hoc Duncan was used to analyze the data. A significance level of $p < .05$ was maintained throughout the experiment.

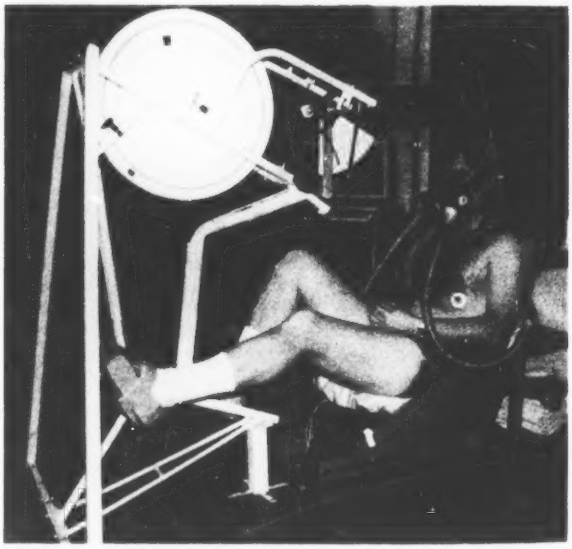

Figure 1. Illustration of the Recumbent Bicycle Ergometer.

Results

Mean oxygen uptake (VO_2) at all submaximal power outputs (PO) for both ergometers is presented in Figure 2. Differences between VO_2, PO, and minute ventilation (VE) between ergometers were not significant at any PO. Heart rate (HR) was similar during the first three PO levels, however it was significantly higher for BERG during the final stage (138 vs 159 bpm; $p, < .05$). VE and local (L) RPE was significantly higher during recumbent cycling only during the highest PO (R-BERG: 77.5 vs BERG: 71.4 l/min^{-1} and L: 6.7 vs 5.6, respectively).

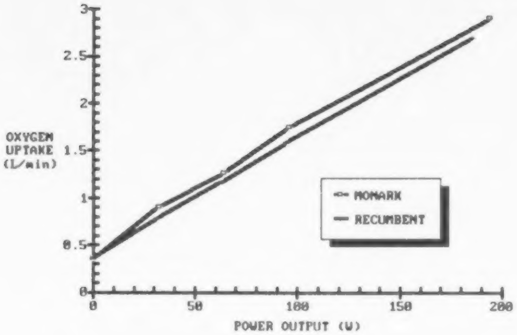

Figure 2. Mean Oxygen Uptake During Submaximal Upright and Recumbent Cycling.

Discussion

Assessment of physical performance of clinical populations is becoming increasingly specific. Problems central to developing new, or modifying existing ergometry, are of a practical and methodological nature. The present investigation has addressed both issues.

The present R-BERG design provides a form of ergometry that reduces balance and postural requirements. A previous model of the present ergometer has been validated for use in water (3). The advantages of the latter application are enhanced heat dissipation and additional upper body support.

Involvement of sufficient musculature to elicit cardiorespiratory responses comparable to conventional BERG does not appear to be problematic. Comparison of metabolic data shows the VO_2 at a given PO to be slightly ($p > .05$) higher using BERG, which might suggest R-BERG to be somewhat more mechanically efficient. The additional O_2 consumption in the former may be attributed to non-measured work performed by upper-body musculature for stabilization. During the R-BERG tests each subject was instructed to place arms and hands in a non-working, comfortable position on his/her lap.

A significantly higher local RPE concomitant with an 8% higher VE during R-BERG cycling might indicate a greater utilization of anaerobic metabolism. Participants subjectively reported that muscular stress during R-BERG cycling felt concentrated within a smaller, more isolated area of the thigh. If the work is distributed over fewer or different muscles as an effect of the recumbent position, a VO_2 max test might be compromised by local stress and/or fatigue before circulatory limits are reached. However, habituation to this ergometer might change this response. Nevertheless, the VO_2 values elicited at all PO levels are more similar to upright cycling values than those reported during arm crank ergometry (65-80% leg VO_2)(1).

Conclusion

The present ergometer appears to be a valid mode for examining aerobic exercise performance. The results during submaximal PO levels are similar to upright cycling, therefore its use might be a more appropriate form of testing and training of disabled individuals who have adequate lower extremity function.

Acknowledgements

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CARDIOVASCULAR RESPONSES TO EXERCISE IN YOUNG AND MIDDLE-AGED SCI SUBJECTS

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INTRODUCTION

Although the effects of aging on cardiovascular responses to exercise for able-bodied subjects are well documented in the literature, very little information is available for disabled subjects including those who are spinal cord injured (SCI). Much of the previous work with SCI individuals has been done without regard for subject age or time since injury, two factors which would be expected to influence exercise responses. The SCI population also requires exercise testing and training protocols that are specific to the upper extremities. However most studies of exercise responses for able-bodied subjects have been conducted using lower extremity exercise (ie. treadmill walking or bicycle ergometry). The purpose of this study was to evaluate cardiovascular responses to upper extremity exercise in young and middle-aged SCI subjects.

METHODS

Eight SCI male subjects were divided into two groups based on age, a young group (ages 19-25, x=22 yrs) and a middle-aged group (ages 35-51, x=42 yrs). The average time since injury for the young group was 3.5 years and for the middle-aged group, 16.7 years. Level of injury ranged from C_7 to T_{12} for both groups and was equally distributed between groups. After signing appropriate consent statements and completing the physical examination, the subjects were acclimated to the exercise protocol used in this study. The protocol consisted of light-intensity steady-state arm crank exercise (ACE) performed at 12.25 W (0.5 kp at 60 rpm) using a Monark Rehab Trainer (arm-crank ergometer). Duplicate bouts of exercise were performed at three tilt angles (0, 30, and 70 degrees) for 5 minutes with a 5 minute rest period between bouts.

Response variables which were determined included cardiac output (CO), stroke volume (SV), heart rate (HR), and mean arterial pressure (MAP). Transthoracic impedance cardiography was used to monitor central hemodynamic responses (specifically SV) to ACE during end-expiratory apnea immediately post-exercise. A microcomputer was used to digitize and analyze analog dZ/dt, heart sounds, and ECG waveforms (1). Calculations for HR were made from the R-R intervals of the ECG at the end of each exercise bout. Exercise CO was approximated as the product of post-exercise SV and exercise HR (2). Diastolic (DBP) and systolic (SBP) blood pressures were estimated immediately post-exercise by auscultation. MAP was calculated as DBP + [(SBP + DBP)/3].

Statistical analysis was performed using separate ANOVA's for each of the five dependent variables. Condition (rest and ACE) was the repeated measure with age (young and middle-aged groups) as the between groups factor. A significance level of 5% was used for all comparisons.

RESULTS

Since the mean values of each physiological variable at each tilt angle did not vary between the age groups, they were pooled for further comparisons. Each mean response value, therefore, would be applicable at any of the three tilt angles used in the study (0, 30, and 70°). The CO (shown in Figure 1) was significantly less in the middle-aged group during ACE by 39% (or 3.65 L/min). CO was not significantly different between the age groups at rest.

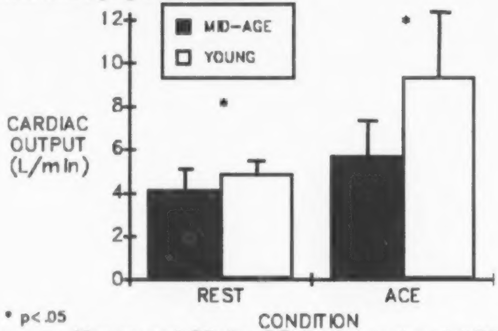

Figure 1. **Means and SD for CO during rest and ACE for each age group.**

The ANOVA for SV showed a significant first order interaction between age and condition, which is shown graphically in Figure 2. Mean SV for the middle-aged group was significantly lower than the young group at rest by 28% (or 20 ml) and during ACE by 45% (or 37 ml).

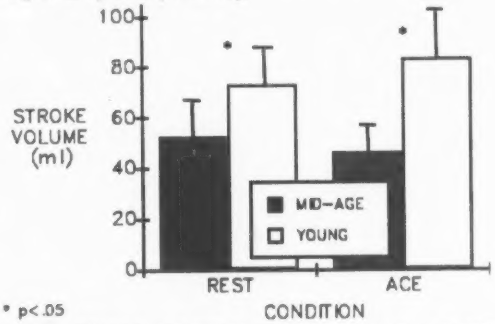

Figure 2. **Means and SD for SV during rest and ACE for each age group.**

The middle-aged group showed a tendency toward a higher HR compared to the young group although the differences were not statistically significant. Analysis of MAP data showed no significant interactions. The middle-aged group demonstrated a significantly higher MAP (108 ± 8 mmHg) than the young group (98 ± 11 mmHg).

DISCUSSION AND CONCLUSIONS

Comparison of cardiovascular responses of SCI to able-bodied subjects is difficult and has created controversy in the literature (3,4,5). The lower CO response to exercise in middle-aged SCI subjects when compared to the young group may be related to physical deconditioning and/or sympathetic cardiac and vasomotor dysfunction. Aging and time since injury, therefore, may further compromise the already hypokinetic circulation of the SCI population.

Although HR tended to be higher in the middle-aged group (by 11 bpm at rest and 19 bpm during ACE), the difference between groups was not statistically significant. Therefore, the low CO in the middle-aged group may be primarily accounted for by low SV. Plausible reasons for the hypokinetic SV response of the middle-aged SCI group may include (a) low myocardial contractility secondary to restricted circulating catecholamine levels, and/or (b) limited cardiac preload and venous return in response to low circulating blood volume which can result from physical deconditioning or excessive venous pooling in the legs.

The higher MAP values found for the middle-aged SCI group may reflect increased peripheral vascular resistance possibly caused by atherosclerosis or renovascular problems which tend to occur with aging.

In conclusion, the SCI age group differences found for SV, CO, and MAP support the cardiovascular changes found with young and middle-aged age groups in able-bodied studies (6,7). These effects may reflect the time since injury as well as the absolute age differences since the middle-aged group's average time since injury was five times that of the young group. This study supports the hypothesis that middle-aged and young SCI subjects differ in their responses to exercise. As Trieschmann states in her book on aging with a disability, because cardiovascular problems are highly correlated with aging, any study conducted with disabled subjects must control for age (8). More research into responses to exercise in SCI subjects is needed which independently controls for both age and time since injury.

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A POSTURE CONTROL SYSTEM BY AUTOMATIC BALANCING MACHINE

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1. INTRODUCTION

The present method used in a rehabilitaion for walking is chiefly training utilizing the parallel bars. As a training of previous stage, a man-to-man training between the patient and a physical therapist is conducted to improve the ability of maintenance for standing balance. This is an autonomous training for external force to maintain a posture by himself. The objects of this study are handicapped persons who need a trainning to walk. We have developed the equipment to make an oscillatory motion of floor mechanically which the patient stand as an technical valuation method of maintenance ability of balance in a standing pose.
This is a system to detect a change of balance as a change of moment by a counterreaction of shoe by giving forcibly an oscillatory motion to the body as an external force. The moment value shows a maintenance ability of balance as a fixed quantity. And the valuation system is expressed as a change of the center of gravity in a oscillatory motion by detecting an angle change of the body using an electronic inclinometer.

2. OUTLINE OF THIS SYSTEM

Driving device part is composed of gimbals structure and has a control system to be able to generate a smooth coupling oscillation of rolling and pitching.
As an actuator, two brushless motors are utilized for the generation of an oscillatory motion. The maximum oscillatory motion angle ±25°can be obtained from these actuators by deceleration through gears. And then, the actuator is used not only to generate oscillatory motions but to have an function of sensor measuring a change condition of balance of the subject.
A real change of balance alone can be obtained by getting difference (A-B) between the balance change of subject (A) and the instruction value (B). By the experimental equipment of this study, a torque change of motor (a real change of balance) can be obtained proportionally through isolate amplifier. Fig.1 shows a moment of measuring data.

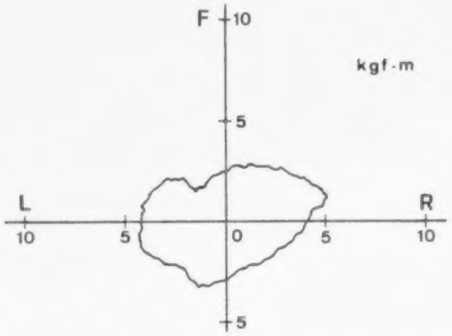

Figure 1 Moment of Oscillatory Motion

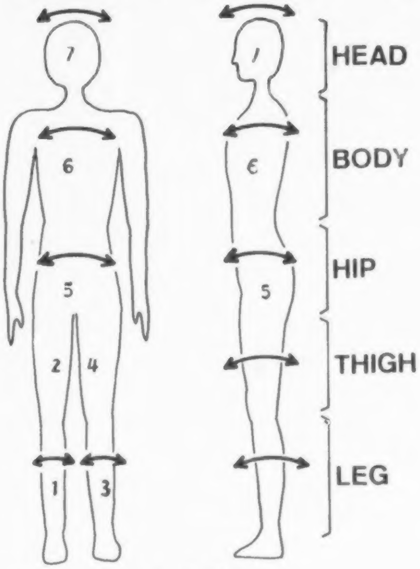

Figure 2 Physical Model

3. THE PHYSICAL MODEL FOR CALCULATION OF CENTER OF GRAVITY

We defined a physical model as a column to obtain the human center of gravity point as shown in Fig.2. In this system, we have measured before and behind, right and left angle of inclination in each segment and become possible to calculate the center of gravity point $Pgi\ (xgi, ygi, zgi)$.
And then, the total coordinate of the center of gravity point $Pg(Xg, Yg, Zg)$ can be obtained

by equation (1). *Wi* in equation shows each weight of segment. We defined the ratio of length and weight of each segment.

$$X_G = \sum_{i=1}^{7} W_i \cdot x_{Gi} \Big/ \sum_{i=1}^{7} W_i$$
$$Y_G = \sum_{i=1}^{7} W_i \cdot y_{Gi} \Big/ \sum_{i=1}^{7} W_i \qquad \ldots\ldots(1)$$
$$Z_G = \sum_{i=1}^{7} W_i \cdot z_{Gi} \Big/ \sum_{i=1}^{7} W_i$$

4. MEASURING EXPERIMENT OF THE CENTER OF GRAVITY

Several tests are made for healthy men. We measured a change condition of moment and an angle of inclination of each segment when we gave a rotational oscillatory motion at a fixed period to the subject standing in a fixed position of opening his foot a little. And the test was performed in the condition with his eyes open.

Fig.3 shows the angular displacement of right and left of upper segment and Fig.4 shows the averaging result of moment as an operative example of data processing of the experimental result (the condition of oscillatory motion:angle ±5°, period;4s, right rotation) of a man of twenty three (height;171cm, weight 68kg).

In this test case, the center of gravity point moved about 120mm in the direction of before and behind, about 115mm in the direction of right and left. But it became clear that the difference between maximum and minimum coordinates was about 5mm and so the center of gravity point didn't move in the vertical direction.

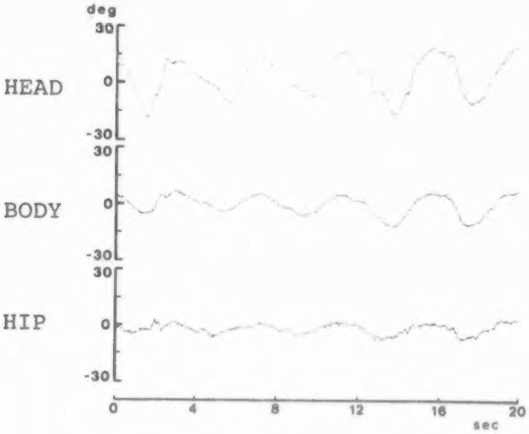

Figure 3 Angular Displacement

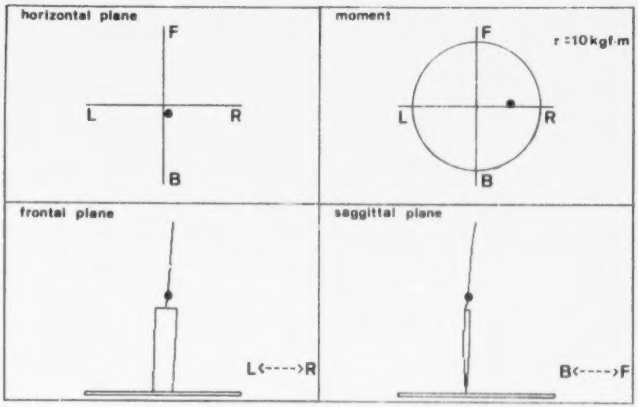

Figure 4 Graphic Display

5. CONCLUSION

As compared a man of health with a handicapped person of the same physique by the basic experiment for paralysis by hypertension, the change of a handicapped person is larger than a man of health in the results of the change of moment by a counterreaction of shoe. This is because the movement amount of the center of gravity point of a handicapped person is larger than a man of health and easily deformed his balance for the oscillatory motion. This is considered as an obstruction of walking in daily life. The unstable conditions of foot are not few in daily life as to walk on the bedding. It is easy to understand for an operator (or a patient) to indicate a change of balance on CRT as a change of the center of gravity point.

In a case of rehabilitation training, the effect of training in the future can be expected as a handicapped person has his own aim. And then, it is considered as a useful application to conduct a measuring experiment for many subjects and to change the results into the data base in this system.

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DESIGN AND DEVELOPMENT OF INSTRUMENTATION TO QUANTIFY POSTURAL STABILITY WHILE SITTING

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INTRODUCTION

Research in the area of motor control suggests that efficient positioning of body segments and the maintenance of stability are important prerequisites to skillful motor performance (3). Postural reactions are used to maintain body alignment and proper posture during the performance of motor skills (1).

Postural adjustments to maintain equilibrium occur automatically in non-impaired individuals with little conscious attention directed toward positioning or balance. This allows the performer to concentrate attention on the execution of the motor skill (3). Children exhibiting neuromuscular impairments often must direct significant voluntary effort at maintaining stability, thereby, decreasing the attention that may be directed toward motor control.

Proper positioning and seating of children with neuromuscular impairments are important factors contributing to optimal development and improved functional ability (2). Improved postural control is a prerequisite to successful school performance, wheelchair mobility, and the acquisition of recreational and occupational skills.

Stability of the trunk appears to be an important prerequisite to the development of upper extremity motor control. A primary objective of specialized seating for the child with neurological involvement is to increase postural stability and allow for increased functional ability of the upper extremity.

PURPOSE

The purpose of this project was to develop instrumentation to quantify seated postural stability of children with cerebral palsy.

DESIGN AND CONSTRUCTION

An adjustable chair frame was designed to provide a stable base for a Kistler measuring platform. Backrest inclination, seat depth, knee flexion, leg length, and seat-surface inclination were made adjustable to accommodate for varying anthropometric characteristics and experimental conditions. All adjustable components of the chair were engineered to insure proper body alignment of subjects ranging in age between 4 years and adulthood (Figure 1).

Welded tubular aluminum (1 1/2 inch) was used in construction to provide a lightweight, stable base for the measuring platform.

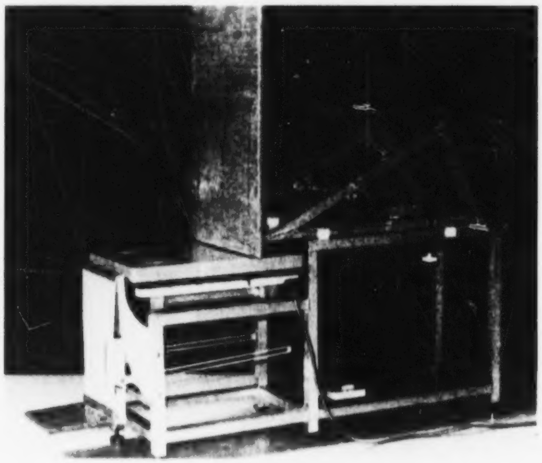

Figure 1 Adjustable chair frame with measuring platform

Sliding surfaces were interfaced with teflon pads and pivoting segments were custom machined. A Kistler multi-component measuring platform was mounted into the frame and incorporated as the seat surface. No part of the chair frame contacts the measuring platform which was secured to the chair frame using a standard mounting bracket. Leveling of the frame was accomplished with adjustable foot pads.

INSTRUMENTATION

Instrumentation consists of a Kistler multi-component measuring platform (9281B) used to transform force into electrical charges. This plate consists of four 3-component (Fx, Fy, and Fz) force transducers. An eight channel (9861A) charge amplifier is used to convert the output signals of the platform into proportional voltages representing magnitude of force. Analog outputs of the transducers are interconnected to yield eight analog signals used to calculate point of force application.

Analog signals are input to an IBM PC/XT computer through a 12 bit analog to digital converter (Data Translation 2801). Software samples data, averages forces, calculates the resultant force and the coordinates of the intersection point of the line of action with the working plane (ax, ay). Data are sampled at 100 hz and stored for analysis at the conclusion of a trial. Data is visually monitored using an analog device to identify sources of error during the data collection session. If data is collected over an extended period, information is periodically stored on disk and the measurement platform is reset to reduce the influence of signal drift.

DATA ANALYSIS

Data obtained from this equipment provides valuable information on selected parameters of postural stability including magnitude and point of application. Force data is digitized and input to the computer over a preselected time period. Each trial consists of a designated number of sampling periods.

The magnitude of the resultant force and the coordinates of the point of force application are calculated for each of the sampling periods and total trial. Variance of these data provide an indication of postural stability and physical comfort (Figure 2).

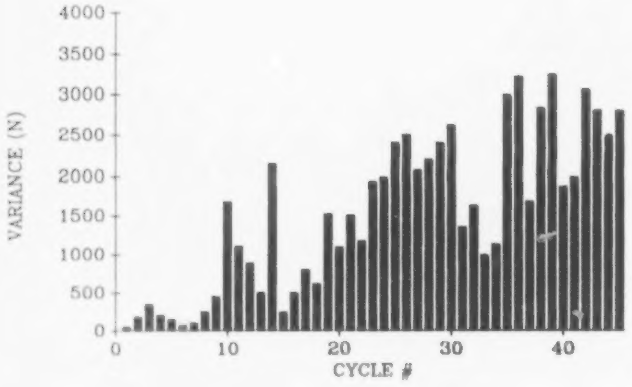

Figure 2 Variance of resultant force for each sampling period

These data are analyzed using statistical analysis and plotted to provide a visual representation of the trial. Figure 3 is an example plot depicting the point of force application data of a subject while positioned at an 8 degree anterior tilt.

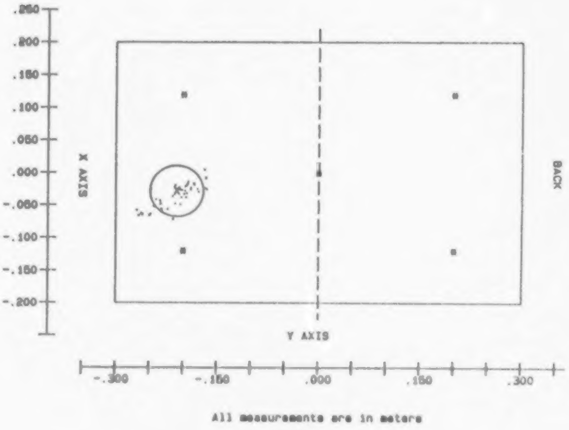

Figure 3 Point of force application.
Note: Individual points represent each sampling period, + trial mean, and circle trial variability.

This instrumentation is currently being used to evaluate changes in postural stability of children with cerebral palsy with varying seat inclination. Future work will involve the collection of data on the maintenance of postural stability during the performance of upper extremity motor tasks.

ACKNOWLEDGEMENTS

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THE REHABILITATION INSTITUTE OF CHICAGO PRECISE MANAGEMENT OF DATA (PMD) SYSTEM

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INTRODUCTION

The Rehabilitation Institute of Chicago PMD system was developed to facilitate clinical decision-making. Decisions about an individual patient's admission, discharge, readmission, placement, referral, and the types of therapeutic procedures to be applied are the focus of the system. The suitability of experimental analysis applied to the field of rehabilition, in which rate of recovery, plateauing, and costs and benefits are common issues, has been described by Wood (9) and many others. Such analysis permits administrators and clinicians to allocate rehabilitation resources efficiently for each individual patient. The PMD system is ideally suited to such experimental analysis. A virtue of the system is that the data are both objective and ratio-quality, which permits comparison of different sites and makes independent evaluation by third party payors or accrediting agencies more feasible (7).

Precise, frequent measurement of progress permits comparison of the benefits of existing and experimental treatment procedures for individual patients and across patient groups. Logical inference about causality requires that interventions be measured with the same precision as patient behavior.
The practical requirements for such a system are stringent: tools must be precise, immediately available, reliable, valid, accurate, and easy for any researcher or clinician to interpret and act upon. Data must be collected, protected, analyzed, and reported, all with a minimum burden to the busy clinician. All PMD software is directed to this end.

The directness of the measurement principles in PMD allows uniform analysis procedures to be applied to data collected by a variety of clinical disciplines. The data display system (described elsewhere in this volume) is the same across disciplines; it is visual and easy to read. Levels of performance and trends can both be seen. Cost-effective decisions can be made, demonstrated, and replicated.

SYSTEM DESCRIPTION

PMD (Precise Management of Data system).
PMD is the family of three packages of software (PDQ, MOMS, and DADS) which are selected (or modified) as needed for an application.

PDQ (Precise Data acQuisition modules). PDQ modules are the hardware and software which are used to collect data and provide real-time feedback (signals and cues) to the patient or clinician. The Timer-Logger-Communicator (TLC) is a PDQ module which monitors wheelchair pressure-relief behavior (1,4,5,6). Five "Cognitive Rehabilitation" PDQ modules provide training in logical operations for persons with brain injury (2). The Communication Analysis System (3) is a PDQ module which supports real-time recording of over 20 critical communicative behaviors between Speech-Language Pathologists and patients with aphasia. Three PDQ modules to collect extremity movement data have been developed; one of these is an inexpensive method for assessing gait symmetry in persons with hemiplegia resulting from CVAs (8). Additional PDQ modules using the TLC technology are being considered.

MOMS (Master Organizer, Manager, Saver module). MOMS is the interface between the clinician and the PDQ modules. MOMS instructs the PDQ and later collects data from the PDQ. MOMS makes sure that the PDQ modules are properly set up for each patient's treatment or intervention; it verifies the accuracy of file information (date, time, patient number, etc.) and of the data collected. MOMS is like a library system, in that it organizes all data, and prevents one patient's from being mixed with another's or otherwise contaminated. MOMS files the data with the correct file identifiers on a floppy or hard disk, and calls DADS when data are to be analyzed.

DADS (Data Analysis/Decision Support program). DADS (discussed elsewhere in this volume) displays the clinical data to assist the clinician in controlling the course of treatment for optimum outcomes. In addition to a series of reports which list events or combinations of events, two DADS modules display within-session data and across-session data. With the latter, the clinician can see trends and variability in patient performance over sessions, and rapidly answer the question, "Should we make a change today?" The "within session" displays address the question, "What really happened during the data recording on day 'x'?" These data can be particularly useful if two or more approaches to the same end were tried during the session. Finally, various statistical summaries are supported within the system, and data export to use commercial software for more complex numerical and statistical treatment is being developed.

Commands. Approximately 100 commands are currently available in the system. Macros are supported. Novice users can begin with only a few commands, and learn others as needed.

Hardware. The PMD system currently uses the Apple IIe, c, or gs as a host. Some PDQ modules run on the Apple, while some use specialized smaller devices that are portable and less expensive, such as the TLC. Translation of the PMD system into a higher-level language is envisioned, so that IBM and Apple Macintosh personal computers can use the system.

CONCLUSIONS

The PMD system provides a framework for the development of an integrated system for the application of scientific analysis to the rehabilitation of each patient. Compatibility is maintained throughout the system, so that data and tools developed in one discipline will be available for use with the data collected in other disciplines. The use of modular programming allows improvements to elements of the system without disruption of the whole. Ultimately, the system will be disseminated to end-users in the various clinical disciplines with different combinations of modules being applied to different clinical issues.

ACKNOWLEDGEMENTS

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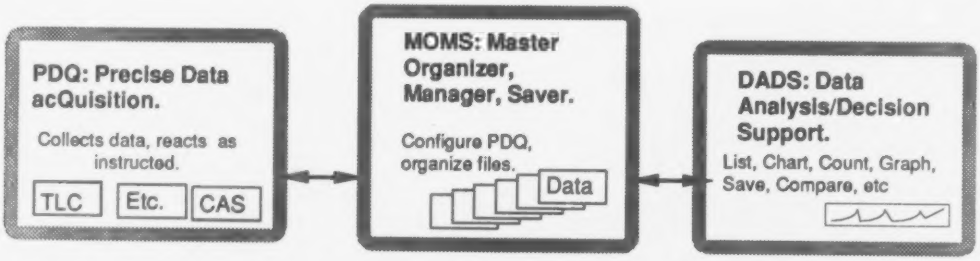
PDQ: Precise Data acQuisition.
Collects data, reacts as instructed.
TLC
Etc.
CAS
MOMS: Master Organizer, Manager, Saver.
Configure PDQ, organize files.
Data
DADS: Data Analysis/Decision Support.
List, Chart, Count, Graph, Save, Compare, etc

Fig. 1. Relationships of the elements of the RIC Precise Management of Data System.

THE REHABILITATION INSTITUTE OF CHICAGO DATA ANALYSIS/DECISION SUPPORT (DADS) SYSTEM

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INTRODUCTION

Psychologists, Nurses, OTs, PTs, and other clinicians in rehabilitation often work with clients on behavior change goals such as better communication, improved gait, better ADL performance, etc. When clients are seen repeatedly, the clinician can use an experimental analysis strategy to determine the optimum intervention for that individual. Basing inferences about behavior on measurement and analysis of its fundamental dimensional quantities has long been practiced in the laboratory (1,6). While the theoretical rationale of this strategy has been widely accepted, collecting and displaying the large amounts of data required is costly. Therefore, this strategy has been less widely used in the routine clinical setting. With appropriate software, inexpensive microcomputers make technically possible routine, cost-effective use of research-quality measures and single-subject experimental designs with each individual clinical patient.

System Environment

The Precise Management of Data (PMD) system, developed at the Rehabilitation Institute of Chicago, (presented in this volume and elsewhere: 2,3,5) is designed to facilitate the routine use of experimental analysis to achieve clinical goals. The system includes data acquisition, data management, and data analysis modules. The present report focuses on the Data Analysis/ Decision Support (DADS) component of the PMD system.

Data file design. Data are stored in the RIC Single File Format (SFF). Each clinical or data collection session is saved as one file in the SFF. The format has three parts. First, a **header** contains comments, names of persons involved, identifiers, the timebase of the data (seconds, tenths, hundredths, or thousanths of seconds) and similar information. Second, the data are kept in a repeating **three-byte format**. As events occur, the type of event is encoded in one byte and the time of occurrence in two bytes. The system can record up to 255 different types of behaviors and events over an essentially unlimited duration. Third, the **filename** is controlled by the system to keep files organized.

DATA ANALYSIS/DECISION SUPPORT OVERVIEW

Hardware environment

DADS operates on any Apple IIe, c, or gs with at least 128K and one disk drive. A mouse is supported within some graphics but is not required. The dot-matrix Apple Imagewriter prints both text and graphic reports.

Functional components

DADS is command driven, with over 100 commands (and macros) now supported. Following is a brief description of the major functional components.

Disk access. DADS uses Apple's ProDos and supports both prefixes/pathname and drive or slot specification. One command arranges the files by type and allows the user to scroll through, select and load files. Logical operators can be used to select groups.

Data listing and editing. Once a file has been loaded, data and comments can be listed to the screen or printer in several formats. Short descriptive labels are assigned to the event codes used in each data acquisition module. Lists, sorts, counts, etc can be generated for analysis, showing the time of each event, the numeric event code, and/or the associated label as desired. Events or sequences of events in any portion of the file can be tabulated. Frequencies and elapsed times between events can be reported. "Wild cards" and logical operators (<,>,#,=) can be applied to the events to report or include only selected events. Temporary labels can be assigned for analysis; the files can then be saved as 'Modified'. Finally, two screen-oriented editors allow for cut, paste, deletion, addition, manipulation, and correction of files.

Within-session data display. Events in any file can be displayed against time as event records or cumulative records (Fig.1). Cumulative and event records can be mixed on the screen in a user-defined format. Phase lines can be drawn as needed. A range of timescales between 7 s and 24 h per screen width can be selected, and the user may scroll or jump through the record if it exceeds the size of the screen viewing area, and make hard copies. Within this module the user can scroll, search, tabulate, etc. and display any portion of a file either as a list or a graphic. Files can be loaded and examined without disturbing the format, so progress can be visualized easily over successive clinical sessions. Chart formats may be saved to disk and later recalled.

Between-session data display. Frequencies of occurrence of any event or sequence can be plotted across days using an adapted "Standard Celeration Chart" (4). Five log cycles are displayed across 123 successive calendar days, allowing the user to see level, trend (celeration) and variability of the data across sessions. Lists of sessions selected for display can be saved to disk. The graphic display is cleared by command, and successive plots use different symbols; plots can be superimposed. Clicking the mouse on any data point will load that session's file for examination.

Comparing files. Two files may be compared to determine the extent to which they correspond, as to assess observer reliability. After selection of two files, the user can mark segments for comparison, or can count, calculate elapsed times, or otherwise examine the files. The user can select corresponding events in each file; DADS then recalculates all times in one file as offsets of that event, synchronizing both files in elapsed time. The user can specify a time "window" within which identical events in the two files are considered to match. Both files can be displayed (or printed) using a split-screen format; matched events are paired and summary statistics are provided.

CONCLUSIONS

DADS provides displays and summaries designed to reveal levels, trends, and variability in the clinical data, permitting cost-effective decisions to be made by the clinician or administrator. Thus, DADS eases routine, cost- effective use of research-quality measures and single-subject experimental designs for the behavioral goals of each individual client.

ACKNOWLEDGEMENTS

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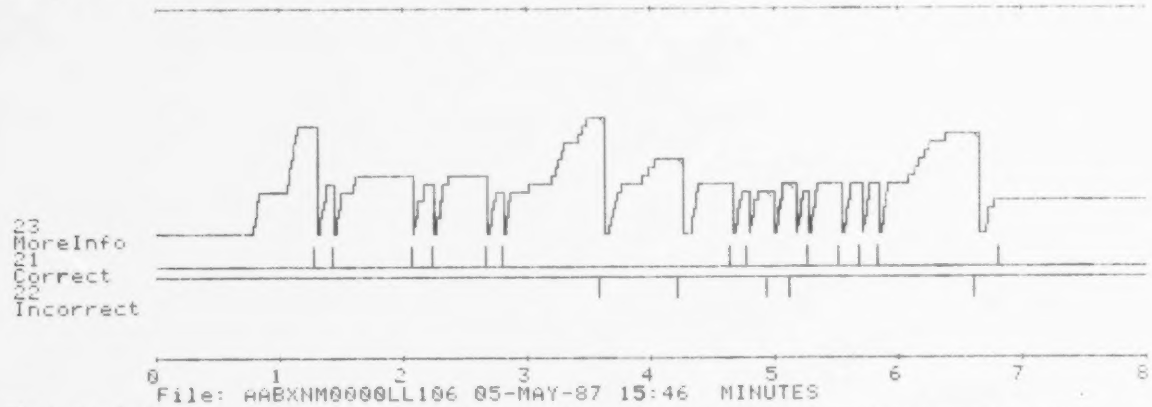

Fig.1. Cumulative plot of data from one 'cognitive retraining' session. A logical problem is presented on the Apple's screen. The patient requests information by pressing the spacebar or registers an inference (answer) by selecting a key from a range on the keyboard. The upper tracing shows information requests. The event record in the center shows correct inferences, and the lower record shows errors. Note the 'plateaus' in the upper tracing.

Biofeedback System for Post-Operative Hand Rehabilitation

D.C. Neth, K.C. Waters, S.S. Staz, S.I. Reger

INTRODUCTION

A biofeedback device has been developed for use in post-operative rehabilitation of the hand. A varied program of exercise can be prescribed and monitored by adjusting the different settings on the device. The patient is asked to squeeze a rubber bulb which is attached to the biofeedback unit. The force of the squeeze, as well as the duration and frequency of squeezing, is monitored. If the patient fails to squeeze the bulb the prescribed number of times and with the prescribed force, a warning light will be activated. If the patient still fails to squeeze the bulb in the prescribed manner, a buzzer will sound. When used with children, the capability of turning off a television or record player has been provided to serve as an effective incentive for exercise. A photograph of the biofeedback device is shown in Figure 1.

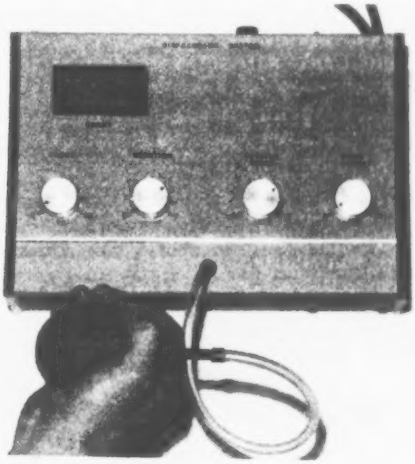

Figure 1: Biofeedback Device

METHOD OF OPERATION

The biofeedback system is initially set up by the clinician according to the desired rehabilitation plan. A number of parameters are selectable. The desired force of the squeeze can be set at one of seven levels ranging from 2 kg to 30 kg. The desired duration can be set to one of eight values ranging from 0 to 7 seconds. Both the warning timer and the final timer can be set to one of eight values from 8 to 15 seconds.

A flow diagram for the biofeedback system is shown in Figure 2. The patient is asked to squeeze the rubber bulb. If both the force and duration of the squeeze are valid, the event counter is incremented and all of the timers are reset. If the patient fails to squeeze the bulb hard enough or long enough, then the warning timer is activated. If the patient responds with a valid squeeze then all of the timers are reset and the event counter is incremented. Failure to respond results in the activation of an intermittent warning buzzer. In addition, the final timer is activated providing the patient with a grace period in which to respond. If a valid squeeze is detected, the buzzer is deactivated, the timers are reset, and the event counter is incremented. If the patient still fails to respond then the buzzer is sounded continuously. At this point the power is removed from the output turning off the patient's television or record player.

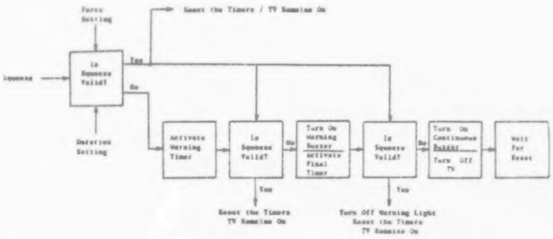
Force Setting
Reset the Timers / TV Remains On
Squeeze
Is Squeeze Valid?
Yes
No
Duration Setting
Activate Warning Timer
Is Squeeze Valid?
No
Turn On Warning Buzzer
Activate Final Timer
Is Squeeze Valid?
No
Turn On Continuous Buzzer
Turn Off TV
Wait For Reset
Yes
Reset the Timers
TV Remains On
Yes
Turn Off Warning Light
Reset the Timers
TV Remains On

Figure 2: Biofeedback System Flow Diagram

CONCLUSION

Initial assessment of the biofeedback system has demonstrated that the device provides a dependable, safe, and effective approach to post-operative rehabilitation of the hand. Future plans will involve a number of clinical trials with patients from the Department of Occupational Therapy of The Cleveland Clinic Foundation. The first study will assess the effectiveness of the biofeedback device in the rehabilitation of patients following surgery for carpal tunnel syndrome. The biofeedback system promises to improve the process of rehabilitation following surgery of the hand.

ACKNOWLEDGEMENT

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Technology for People With Disabilities: Developing A Blue Print for Action

Rachel Wobschall, Director
Governor's Initiative on Technology for People with Disabilities

INTRODUCTION

In recent years, there has been a tremendous acceleration in the rate of technological innovation, with new devices and processes being developed that can enhance the daily lives and activities of people with disabilities. An enormous range of technological devices are potentially available to help individuals function more fully in areas such as mobility, communication, and the negotiation and control of their environment. Technological advances are also applicable to educational and vocational programs. For persons with disabilities, the availability of assistive devices or technology-related services can mean the difference between employment or unemployment, independent or dependent living, and the ability or inability to participate in the normal, everyday affairs of a community. Action is needed to ensure that technological devices and services are available and accessible to people with disabilities.

METHODS

In October 1985, Governor Perpich of Minnesota announced an Issue Team on Technology for People with Disabilities created to investigate the potential of high technology to improve the quality of life for Minnesotans with disabilities.

Over the next six months, the Issue Team explored ways to increase awareness for users, the public, and professionals to provide access to appropriate technology based products and services and to fund research and development that addressed the critical needs in this field.

RESULTS

As a result of the findings of the Issue Team, the 1987 Minnesota State Legislature created the Governor's Advisory Council on Technology for People with Disabilities.

Drawing on the expertise of its members from the public and private sectors, the Council advises the Governor on public policy that promotes development, funding, and dissemination of technologies for persons with disabilities. Representatives from all state agencies serving persons with disabilities are also members of the council. Thus, the Council acts as a catalyst advancing the use of appropriate technologies within these agencies.

DISCUSSION

Discussion during this presentation will focus on the following issues:

- The formation of effective public-private partnerships to increase awareness of technology for persons with disabilities.
- The role of state initiatives in the national and international public policy process.
- Specific development projects that have been initiated by the Council.
- The success and frustration experienced by the council in trying to impact public policy in this diverse and rapidly changing area.

CONCLUSION

Minnesota's economy has prospered from the strong base of technology intensive firms, a spirit of cooperation, and an abiding concern for our citizens. These same strengths give us the ability to lead the nation in the application of technology to the needs of persons with disabilities. Action taken by this council and similar initiatives is crucial to developing the broad public policy agenda that will shape the application and availability of technology for persons with disabilities in the next century.

ENVIRONMENTAL CONTROL UNITS ARE THEY REALLY LUXURY DEVICES?

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ABSTRACT

In the United States funding for environmental control units is generally unavailable via third party payors and governmental funding mechanisms. The philosophy that reimbursement must be tied to medical disability, rather than enhancement of functional ability, needs to be reviewed and changed to allow disabled people to access technology and benefit from the increased independence it can provide.

INTRODUCTION

Basic environmental control units (ECUs) were originally developed for the general, able-bodied public as a means of controlling various electrical devices in one's home through the use of buttons and a central control unit. They have since been modified for use by disabled persons by the addition of specialized features allowing access via various adapted switches, and providing enhanced capability, such as telephone usage and computer accessibility.

Historically, ECUs have been viewed as non-essential, "luxury" devices by the health care financial industry and governmental funding programs. Primarily because they are not prescribed to correct or treat a medical condition, funding for these devices for disabled people has often been denied. Unfortunately, those individuals who are most disabled are often the most in need of these aids to control their environment. They generally have limited amounts of discretionary income to spend on devices. The long-term nature of spinal cord injury, and other permanent disabilities, limits the earning capacity of these individuals greatly, often necessitating public financial support.

FUNDING BASED ON FUNCTIONAL ABILITY

In the United States, the criteria for determining what is reimbursable and what isn't differs from one third-party payor to another. However, most payors will not cover items perceived as not meeting direct medical needs of recipients.

The distinction between medical necessity and functional necessity, is not being addressed by the current health care system. The philosophy of funding for medical necessity needs to be modified toward the view of funding for functional ability.

An attitude change is needed to address and respect the needs of disabled people for increased self-image and independence in a wide spectrum of activities. Why is independence in wheelchair mobility seen as important, and not independence in the use of telephones, lights and alarm/call bells? Why does independence need to be limited to mobility? Why is funding provided for a communication device without allowing the client a way to access a telephone to communicate?

REIMBURSEMENT CRITERIA

The criteria for third-party reimbursement are sufficiently vague to require substantial judgement on the part of individual reviewers regarding the appropriateness of ECUs for rehabilitation purposes. It is extremely difficult for reviewers (many of whom are not practicing clinicians) to stay current in the rapidly changing field of technology. Therefore, decisions are rendered based on past history and somewhat arbitrary guidelines, rather than individualized patient need.

As the need for additional Centers for Rehabilitation Technology is realized, and as clinicians become more skilled in the knowledge and prescription of technical devices, the issue of funding for ECUs, computers, and related technology becomes more obvious. One can foresee a network of technology centers being developed throughout the country, equipped with the latest in technological devices, but unable to provide them if the disabled consumer cannot obtain funding for their acquisition. Should we show these individuals the candy, and then deny it to them? Yes! Just as anyone has the right to visit a Rolls Royce showroom, regardless of their ability to buy a Rolls, so should disabled people have full access to the knowledge of a wide range of ECU and computerized devices which will provide them with greater independence. Once the ideal devices are identified, future funding can be pursued. But the determination of the best unit for an individual should be based on what the individual needs, rather than what he or she can afford.

RECOMMENDATIONS FOR THE FUTURE

- One way of approaching this problem is for Centers for Rehabilitation Technology to establish and maintain good lines of communication with reviewing bodies. This ensures that current information regarding technology is disseminated and that competent rehabilitation technologists are available for consultation by reviewers when questions come up. In addition, clinicians must develop an understanding of regulatory guidelines to avoid submitting inappropriate requests for funding and to establish trust between the two parties. Review bodies can be used to train staff in writing sufficient and appropriate justifications to provide the information for reviewers to make an informed judgement.

- Disabled individuals need to be more vocal in identifying their need for funding and recognition of benefits, both physical and psychological, that technology can provide.

- The health care community has to actively advocate for the need for funding technology for the disabled.

- Governmental funding mechanisms need to be reviewed. Permanent disability as a result of spinal cord injury, trauma, cardiovascular accident, musculoskeletal diseases and cerebral palsy does not disable a person's mind. Technology can provide the means of accessing the remaining abilities of the disabled person and can harness these abilities to enable the individual to be as independent and productive as possible. It is hard to measure the value of this freedom. If a disabled person can stay alone for several hours or a day because he or she has access to a telephone for emergencies, can activate a call bell or a door alarm system, and has a means of lighting his or her environment, does this justify the cost of an ECU? What are the long term savings in health care personnel costs over the life span of the individual if home health care is not needed to monitor the person? Will the ECU provide access to a computer which will lead to increased communication and perhaps vocational readiness? Consideration of these questions and their possible solutions needs to be included in the development of public policy regarding health care funding.

- Alternate funding sources need to be explored. Increasing use of community service agencies to fund special technology evaluation centers and their clients should be encouraged.

CONCLUSION

The field of rehabilitation technology is progressing at a much greater rate than health care funding mechanisms. When the health care financial community addresses the functional capabilities of an individual and provides the support needed to ensure that these abilities are used, the quality of life for disabled people will progress in step with technololgy.

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A NEW APPROACH TO REHABILITATION: A CONSUMER'S PERSPECTIVE

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Society's awareness of unique potentials found within members of the disabled community has increased notably since the International Year of the Disabled was proclaimed in 1981.

The expanding consciousness produced by this phenomenon has stimulated the creative abilities of numerous techno-experts and rehabilitation specialists. Medical technology has, in particular, excited the imagination and motivated eager research for improving the quality of life of persons affected by disabling ailments.

In many instances, however, poorly diagnosed social conflicts have resulted and it has become evident that socio-cultural views and rehabilitation objectives for the disabled need to be reviewed.

The concept of rehabilitation discussed in this paper is presented from the perspective of a former health-care provider, as well as a disabled consumer who has depended extensively upon medical and social services for rehabilitation support.

ANALYSIS

The sources of conflicts mentioned above are described by Kurtz and Chalifant(1) who analyse role models and social status of illness as defined by theorists such as Parsons(2), Freidson, Rosengren and Zola,(3),(4),(5), and others.

Parsons' paradigm on the role and social status of illness describes sickness as a condition which an individual may seek legitimately, but will obtain only upon social approval. Once the individual is granted the sickness status,he/she is temporarily excused from social responsibilities. Consequently, the social conscience dictates that society provides the sick person with help and support necessary for a successful recovery.

However, once the claim for entry into the sickness status is accepted, individuals must willingly surrender their decision-making ability to "social control agents" or "gatekeepers",(1)p.86, who dictate the sequences of the ascribed role. The appointed agents consist mainly of health-care delivery personnel, social agency staff, community and spiritual leaders and educators.

Furthermore, if the social control agents agree that a chronic or permanant claim to the sickness status is justifiable the appropriate dispensation from social duties will be granted as part of the social order ideology.

In some instances, however, claims to the sickness status do not appear to justify an exemption, or the claimant is unwilling to conform to the prescribed role. Such action will demand a socially punitive response which, in drastic cases, will ostricize the claimant from all group activities.

Based on the preceding arguments, it can be demonstrated that the medical or sickness role model ascribed to disabled persons conflicts constantly with the aims of rehabilitation. This can be attributed mainly to the inability of the disabled individuals to comply to the social code of sickness, a violation of the social order theorists label as deviance.

In chapter 4 of their book, "Illness Behavior and Becoming a Patient", Kurtz and Chalifant describe a series of social deviance behavior traditionally associated with the sickness role. The author of this presentation identifies four conditions frequently observed within the disabled population.

1. Prolonged periods of active treatment do not necessarily lead to recovery. Therefore, although there can be occurences of remission, the individual is still excused from social responsibilities. However, the person's wish to (re)-claim part of an active social role, if only temporarily, is firmly denied participation.

2. This denial from society may lead to impulsive, independent ventures requiring high levels of physical and emotional energy. The ensuing state of euphoria or depression will depend on the degree of success or failiure of the endeavor. This, in turn, creates further social conflicts, thus reinforcing the notion of deviancy.

3. The state of rebellion and anger among the disabled population, in particular, is also fuelled by the social expectations that the sick person must surrender personal control of his/her lifestyle to service-providers in order to be socially accepted.

4. Also, an important dimension to individual claims to the privileges of the sickness status by disabled persons and society's response must be examined. They are the persons who use their disability as a mean of avoiding social participation, or an excuse for covering up failiures.

This complex actuality can be observed within all social groups, but the deviant behavior is more readily tolerated from the disabled group because of the inherent sickness status of this social group.

DISCUSSION

From the foregoing anlysis of the social sickness role as ascribed to persons with disabilities in particular, it is evident that the present rehabilitation system is no longer compatible with our rapidly evolving social culture, a result of expanding technology. But it appears conceivable to modify the approach to current rehabilitation concepts while maintaining social order through gradual introduction of innovative social policies.

And it is the view of the author that changes could be initiated by members of educational institutions who train our service-providers, policy-makers, political and community leaders and all others interested.

But the most important adjustment will be that of reverting the concept of the sickness role model. Disabled individuals should be encouraged to participate actively in their rehabilitation experience rather being regarded as mere recipients of social favors; this in turn would stimulate the enhancement of social skills.

With the new challenging resources of technology, complemented by a motivating approach to rehabilitation one can nurture the hope of foreseeing a new, more active social role ascribed for persons with disabilities wishing to integrate. But this dream will be attained only if the disabled individuals are called upon and expected to accept their share of responsibilities.

And only then would we be able to claim that there is a "Choice for All".

CONCLUSION

The traditional medical role model has allowed persons with disabilities to be excused from social responsibilities while society accepts the task of serving as their provider. Such a concept has been frequently observed in rehabilitation programs in the past.

This has deprived disabled individuals from their abilities and rights to control their lifestyle and participate actively in their community, if only on an intermittent basis.

However, dramatic cultural changes are placing this role model for disabled individuals in question. An increased awareness of these persons' abilities to fulfill social responsibilities warrant a fresh outlook on the socially ascribed disabled model, and the role played by service-providers.

And the initiative and duty of formulating revisions appear to fall mainly upon policy-makers educators and service providers.

ACKNOWLEDGMENTS

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DO OUR PAYMENT POLICIES ENCOURAGE DEPENDENCY?

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Rehabilitation Engineering Center

INTRODUCTION

Each of us, as members of the "public," has a vested interest in public policies related to payment for rehabilitation equipment. We have a long-standing record for using public funds to support U.S. citizens who are disabled. That support, provided through a myriad of public agencies, comes in the form of cash assistance, tax credits and direct purchase of products and services.

The products of technology are increasingly being recognized for their potential to help meet medical, educational, vocational and other goals of persons with disabilities. Public policy is evolving to reflect this realization. As legislation is formulated, such as the Rehabilitation Reauthorization Act of 1986 and the TECH Act, we can expect greater public investment in rehabilitation equipment.

Despite this positive trend, one fundamental aspect of our present payment policy remains objectionable. It is ironic that, while technology is being heralded for its potential to improve individual capabilities for independent living, our system of public payment for the products of technology strongly fosters financial dependency among those same individuals.

THE PROBLEM DESCRIBED

Our current public payment policies foster dependency in several ways.

First, dependency is fostered through the complexity and the fragmentation of the public payment system. We do not have a coordinated system. Instead, payment for rehabilitation equipment is the responsibility of a patchwork of public agencies, each with its own program goals, eligibility requirements, coverage policies and payment procedures. This creates a confusing system that requires a great deal of expertise to traverse. There are frequent opportunities for error, where payment is sought from the wrong source, for the wrong equipment, because the wrong information is provided. Many persons do not have the requisite understanding to maneuver effectively within the system. As a result, many find it necessary, and are encouraged to rely upon professional advocates to steer them through the payment maze.

A second form of dependency is the way in which third party payment isolates the equipment user from the equipment selection process. Under a system of third party payment, a second party -- a qualified professional/team -- generally is designated to make the substantive decisions as to what is needed. Theoretically, professional involvement is instituted as a control against misuse of third party funds. Too often, however, another result is that the equipment user is insulated from the selection decision, or, if involved, certain issues/attributes considered important by the end-user (e.g., aesthetics, reliability, convenience, etc.) are subjugated to those deemed necessary by the prescriber and payer (e.g., medical necessity, safety, cost, etc.). There is an implication that the "beneficiary" cannot be trusted to make an appropriate decision regarding use of public funds.

Finally, dependency is also fostered through the way that we pay for rehabilitation products. The vast majority of public dollars are spent to fund rather than finance acquisition of equipment. This distinction in terminology is important. When we fund something, we generally pay most of the costs and expect little, if any, copayment from the recipient. Financing, on the other hand, is a credit payment arrangement. With financing, the end-user is the ultimate payer. Financing is simply a means to make payment more affordable by stretching installments out over time.

Our present public policies emphasize buying equipment for individuals rather than helping them pay for that equipment themselves. Of course, in many cases funding is a very appropriate support. For persons with limited financial resources, funding may be the only way for them to acquire equipment. Similarly, funding is a more direct way for the public to ensure that its funds are used for what is intended. However, funding also engenders more dependency than financing. In addition, there are many persons with disabilities who may be capable of affording more of a financing arrangement. In those cases, funding may actually create a disservice. Buying a product for someone does nothing to help that person establish a credit record, thereby making it more likely that he/she will continue to be dependent upon public funding for equipment over time.

A PUBLIC CHALLENGE

As members of the public, it is our responsibility to reexamine the ways we presently help pay for rehabilitation equipment. We must consider some basic policy questions. Are there persons with disabilities for whom financial support, or some hybrid subsidy, is preferable to funding? How do we offer those alternatives? Can we modify our funding policies to empower greater decision making among end-users? Can the payment system be streamlined so that it is more understandable and therefore more accessible?

In considering these questions, we must recognize that paying for durable equipment is different from paying for services. Unlike services, for example, equipment must be maintained, repaired and replaced over time. In addition, ownership is a unique issue with equipment. Who owns the equipment purchased with public funds? What is done to reclaim the product when it is no longer used? These and other issues unique to equipment warrant attention and require that public policy be reshaped accordingly.

We must also recognize the wide variability in financial status among persons with disabilities. Although many, perhaps the majority, have severely limited financial resources, that is certainly not true universally. There are many who do earn income and who can afford the responsibility of paying for all or a portion of the price of needed equipment.

Ultimately, we must develop a continuum of payment alternatives that address the unique challenges of payment for rehabilitation products, reflect variations in individual financial status, and minimize the dependency created among persons with disabilities. The potential for independent living offered by the products of technology should not be thwarted by poorly designed public payment policies that foster dependency.

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"SPECIAL INTEREST GROUP". 7

Technology Transfer
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LIFESTYLES OF THE NOT-SO-RICH OR FAMOUS: FOCUS GROUP INTERVIEWS WITH DISABLED CONSUMERS

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INTRODUCTION

Interaction with disabled consumers is critical to successful development of rehabilitation technology. One method of consulting with consumers is through the use of focus-group interviews. The purpose of this paper is to describe in some detail the use of focus-group interviews in a needs assessment on rehabilitation technology.

FOCUS-GROUP INTERVIEWS

Focus-group interviews are structured group discussions which typically involve homogeneous groups of 8 to 12 persons, last two to three hours, and are led by a trained moderator. The focus-group discussions are based on a structured moderator's guide which is prepared, rehearsed, piloted, and revised prior to the focus-group interview. The sessions are usually taped and transcribed, and a summary report is written.

Focus-group interviews have become popular in marketing research over the past ten years. They are used for (1) basic studies for product idea creation; (2) product-positioning studies, (3) advertising and communications research; (4) background studies of consumers' frames of reference; and (5) determination of attitudes and behaviors [1]. Less expensive than most mail or telephone surveys, focus groups also allow participants to respond to others' ideas and attitudes. Flexibility and low cost are seen as worthwhile trade-offs against the disadvantages.

One disadvantage of focus groups is that the sample size is small and non-random. (In fact, cost constraints in other surveys of disabled people often lead to the same limitations.) A second disadvantage is greater potential for bias than in other survey methods: Responses are not independent, and bias on the part of the moderator can influence the discussion and/or interpretation of the results.

The objectives of the inquiry and the characteristics of the population must be considered when selecting a method for consulting or surveying consumers. Some situations in which focus-group interviews might prove useful:

-- for assessing needs in areas of rehabilitation technology that have received little development

-- for obtaining objective opinions from ordinary users of technology (not just the technically oriented expert consumers)

-- for learning about attitudes, baseline use of other devices, and insights about field conditions

-- for exploring problems in service delivery, information dissemination, and background factors that influence the use of technology

-- as a precursor to design of a mail or telephone survey

A NEEDS ASSESSMENT

In our needs assessment, the method suited both the needs of the target consumer-group and the nature of the study. Because end-users were severely or profoundly hearing impaired, mail surveys and telephone interviews were ruled out. Mail questionnaires are ineffective with populations of deaf persons who have marginal literacy. Telephone interviews present similar problems because TDD conversations require reading, writing, and much more time than voice conversations.

Another methodological challenge was presented by the topic of the needs assessment. The goal was to solicit creative suggestions about communication problems and technological solutions to those problems.

PROCEDURES USED

Fifteen focus-group interviews were conducted with consumers and service providers (in separate groups) in five states. Local recruiting and facilities arrangements were handled by Gallaudet's Regional Centers and one state office of vocational rehabilitation.

The following precautions were taken, to get the best possible research quality from the methodology:

1. Expert consumers were involved in designing the study.

2. Participants were grouped by at onset of hearing loss. Age at onset of hearing loss relates strongly to communication preference and to use of technology. Within the category of persons deafened at birth or in childhood, we further grouped according to educational level.

3. Moderator's communication skills were matched to the communication preferences of consumers.

4. Moderators communicated directly with participants. Interpreters were not used.

5. Recording methods were adapted to fit each group. For example, in the deaf groups, the hearing person on the team recorded the signed comments of participants into a hand-held recorder.

6. Structured moderators' guides were developed and carefully followed.

7. Moderators underwent a 15-hour training course from a marketing research firm specializing in focus groups.

8. Basic demographic information was collected from participants, for later reference.

9. Suggestions for innovations were recorded on flip charts and their accuracy was verified before proceeding.

10. Several focus-group sessions were conducted for each subgroup of hearing impaired persons.

11. Four consumer experts, one of which had moderated some of the groups, did critiques of the draft report.

AUDIENCE FOR RESULTS

The results of the focus-group discussions are summarized in a 10,000-word report, available from the authors [2]. The report covers consumers' attitudes toward technology currently available, problems and concerns in everyday life that might be addressed through technology, and ideas for future devices. The general topics covered are: face-to-face communication, telecommunication, mass media, and environmental awareness.

The report is being used in two ways: to guide our own staff in development of our program, and to communicate with scientists and engineers about what hearing impaired people are saying they need. We have found engineers to be very interested in the report. It gives a useful overview of the "lifestyles of the deaf and hard of hearing" based on direct consultations with end-users. Hearing impaired consumers have indicated gratification of seeing their opinions documented.

SUGGESTIONS BASED ON THIS EXPERIENCE

We offer the following suggestions to those considering conducting focus-groups in rehabilitation technology:

If at all possible, pay participants for their time. This is standard practice in marketing studies. In this study, each hearing impaired participant was paid $10.

If possible, notify a large number of consumers, include a brief questionnaire with the notification, and issue invitations to those who meet your criteria. This avoids awkward situations, such as having to turn away those who do not meet the criteria.

Avoid mixing disabled users of technology with their family members. If family members' perceptions are important--and often they are--conduct a separate focus group with them. The same principle applies to service providers.

Do not use focus-groups to consult people who are in competition with each other. Business competitors should not be assembled in a group, for example. Also avoid allowing people in supervisory roles to participate in groups which contain subordinates.

The moderator's performance is key to success of the method. The moderator must be neutral, but knowledgeable enough to understand the content of the discussion. If the purpose of the group is to provide input or feedback to the development process, it would be best not to have any of the development staff moderating or otherwise participating in the focus group.

CONCLUSIONS

Rehabilitation engineering can benefit from methods used in marketing research, for the purpose of better understanding of end-users and their concerns. Appropriate use of such tools as focus-groups may lead to more successful efforts at technology transfer.

ACKNOWLEDGEMENT

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BETTER PRODUCT CHOICES WITH COMPARATIVE PRODUCT PERFORMANCE INFORMATION

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The Conference theme, "Choice For All", is intended to draw attention to the vast range of choices technology offers disabled persons. Technology can indeed offer new choices in lifestyles, provided an appropriate choice in the available technology is made.

If the benefits from keen marketplace competition are to be realized, consumers need sufficient product information for making something close to the "most appropriate" choice. As the numbers and types of assistive devices proliferate, making the most appropriate choice becomes increasingly difficult. However, purchasing the wrong assistive device can be an expensive mistake. Wheelchairs, for example, are too expensive to throw away for another more suitable model. "Comparative Product Performance Information" is needed which allows meaningful comparisons of alternative devices before the purchase is made.

COMPARATIVE PRODUCT PERFORMANCE INFORMATION

"Comparative Product Performance Information" is product performance information obtained in accordance with standard tests, and presented in a standardized format permitting fair comparisons of expected product performance.

The distinction between performance and design information is important. Design information is expressed in terms of simple physical attributes such as dimensions, shape, and material, and is needed to assure compatibility or interchangeability between system components. Performance information, on the other hand, is expressed in terms of functional attributes such as product durability and energy efficiency. Unfortunately, these performance or functional attributes are more difficult to measure, and are often more difficult to convey in understandable terms to consumers.

Compared to design information, however, performance information permits better product comparisons. Consider the common light bulb. Performance information such as bulb brightness, energy consumption, and average bulb lifetime is much more helpful to consumers comparing bulbs than design information such as filament diameter, length, and material.

UNIFORM DISCLOSURE STANDARDS

Standard tests are essential for comparing "apples to apples" across brand names. Uniform Disclosure Standards are a relatively new type of product standard which specify (a) the necessary standard test procedures, and (b) the rules for displaying the test data in a standardized format.

Generally, Uniform Disclosure Standards do not contain pass/fail criteria. They are particularly suitable where there are no sharp acceptable/unacceptable thresholds. Some wheelchair users, for example, may be willing to sacrifice durability to get more maneuverability, or vice versa. Appropriate trade-offs depend on an individual's needs and preferences. There is no "best" combination for everybody, so pass/fail criteria are not appropriate in Uniform Disclosure Standards. Fortunately, standards having no pass/fail criteria have almost no risk of unfairly excluding new products from the market. The possibility of restraint of trade has been a serious concern for some standard developers.

The RESNA/ANSI Wheelchair Standard for powered and manual wheelchairs will be the first Uniform Disclosure Standard for assistive devices. Most sections of the Wheelchair Standard are in the final stages of review. Their implementation will involve three additional steps, all of which will require considerable effort: (1) Someone (probably participating manufacturers or vendors) must test wheelchairs in accordance with the test procedures in the standard. (2) The resulting test data must be collected and put in a format allowing reasonably easy product comparisons. At that point, the information becomes Comparative Product Performance Information. (3) This information must be disseminated to those who will benefit from its use. Of course, safeguards must be in place to ensure that the disseminated information is accurate.

EXPECTED BENEFITS

When Comparative Product Performance Information becomes available, impressive benefits can result for both consumers and manufacturers/vendors. Rehabilitation product users, prescribers, and third party payers will be able to make more informed procurement decisions, making it more likely that rehabilitation devices serve the needs of users. Comparative Product Performance Information can be utilized to counter the "low bid syndrome" by helping to justify a legitimate need for a device having better than minimum product performance.

From the manufacturers' and vendors' perspectives, those who offer the best performing products at reasonable prices will be more likely to be rewarded in a market having Comparative Product Performance Information. This will lead to improved marketplace competition, and will encourage the introduction of improved products at competitive prices. Comparative Product Performance Information will assist manufacturers and vendors wanting to supply quality products to compete against inferior products, since the trade-off between quality and costs will be clearer. The dissemination of such performance information by a well known independent organization will be a valuable supplement to regular advertising by participating manufacturers/vendors.

Recent news media publicity about airline service illustrates the potential benefits from the dissemination of performance information. With the disclosure of "on-time arrival" records, supposedly generated using the same counting procedures, the airlines have become increasingly concerned about their performance. While it is true that this example concerns performance of a service rather than a product, it is reasonable to hope for similar benefits from dissemination of product performance information.

Will these expected benefits be realized? Will Uniform Disclosure Standards be developed for assistive devices other than wheelchairs? Can the resulting test data be made understandable and readily available as Comparative Product Performance Information? If so, will consumers utilize this information before making procurement decisions? Only time will tell, but a good start has been made with the Wheelchair Standards.

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EVALUATION OF REHABILITATION DEVICES

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INTRODUCTION

A requirement for the effective introduction of new rehabilitation technology is that there be a comprehensive evaluation covering technical capability, safety, usage by potential clients, and/or usage by professional staff. This evaluation must be interdisciplinary and include technologist, therapist and user perspectives. Without effective evaluation poorly conceived devices may be suggested or obtained leading to increased frustration, wasted financial resources, and possible risks. Furthermore well designed and useful innovations may not come into appropriate use without an evaluation methodology system that adequately assesses and reports on device characteristics. Thus a standard evaluation methodology and reporting system is necessary that will assure meaningful assessment and communication. The outline of such a standard following the ASTM (American Society for Testing and Materials) format is suggested below.

1. SCOPE

1.1 This practice describes a methodology for the evaluation of commercial or custom rehabilitation devices intended for use by individuals with handicaps, or in their therapy. It may also be used for the evaluation of devices being adopted for rehabilitation use although originally designed or marketed for other applications.

1.2 In using this standard it must be remembered that individual users of the candidate device may have unique characteristics and that therefore the applicability of any device must be assessed on an individual basis in addition to the methodology of this standard.

2. GENERAL REQUIREMENTS

2.1 Uses

2.1.1 Rehabilitation Devices- The intended use of a candidate rehabilitation device must be clearly specified by the designer or seller.

2.1.2 Adopted Devices- The intended use of a general purpose device being adopted for rehabilitation must be clearly specified by the person making the recommendation.

2.2 Intended User- The characteristic handicapping conditions and necessary physical and intellectual attributes necessary to use a candidate rehabilitation or adopted device must be specified.

2.3 Technical Achievement

2.3.1 Efficacy- The degree to which the device meets the intended or suggested use in terms of its capabilities to restore, replace or supplement function must be evaluated under real or realistically simulated conditions.

2.3.2 Safety- A system safety analysis should be performed to identify normal operating risks, failure modes, and their consequences.

2.3.3 Reliability- The reliability of the device to continue to function in its actual environment of use should be evaluated and supplemented where possible with field data.

2.3.4 Maintainability- The degree to which the device can be repaired, and the complexity and cost of the repair, should be evaluated based on reasonably anticipated failure modes.

2.4 Human Factors Achievement- The user interface with the device must be evaluated with respect to the target user will be able to achieve the capability of the device under realistic conditions.

2.5 Skills and Training Requirements- The ease or difficulty of application of a device by users and/or therapists should be evaluated in terms of skills, background or training required to correctly select and implement the device.

2.6 Instructions

2.6.1 Devices Intended for Rehabilitation- The instructional material available with the device should be evaluated with respect to clarity and completeness with respect to each of the evaluation factors of 2.1 through 2.5, 2.7, and the general requirements of Section 3.

2.6.2. Adopted Devices- When general purpose devices are being evaluated for rehabilitation applications not intended by the manufacturer, the instructions should be evaluated in this context. The need for and possible sources of supplemental instructions should be considered in the evaluation.

2.7 Systems Integration- Each of the evaluation factors of 2.1 through 2.6 should be considered in the context of how the device will be used in its realistic environment of application including its interaction with other rehabilitative or common devices that can be expected to be used simultaneously.

3. INSTRUCTIONS AND LABELING

3.1 General Requirements- The instructions and labeling for a rehabilitation device should conform with the applicable sections of the U.S. Food and Drug Administration's labeling requirements for medical devices, whether or not the device is formally classified as a medical device.

3.2 Minimum Requirements- Without reducing the requirements of 3.1, the instructions and labeling should contain adequate directions for use including indications, contra-indications, methods and duration of administration, and any hazards or risks. Preventive maintenance instructions are required and the availability of repair instructions or service should be indicated.

3.3 Adopted devices- When general use devices are evaluated for rehabilitation applications the manufacturer can not be held to the requirements of 3.1 and 3.2

4. TEST METHODS

4.1 General Requirements- Since this standard addresses the diverse spectrum of rehabilitative devices it is not possible to specify specific test methods. The general requirements are that test methods meet standards for technical accuracy and reliability and that statistical test principles be followed as appropriate. It is also required that functional tests be conducted under realistic conditions of use and where possible by real target users.

4.2 Reporting- Details of the test methods used should be reported as required in Section 5.

4.3 Documentation- All test data shall be retained and made available at reasonable expense upon request.

5. REPORTING REQUIREMENTS

5.1 General Requirements- A written report should be prepared which provides narrative and/or quantitative results of the evaluations of Section 2 including specific test methods and results of the evaluations in each section.

5.2 Recommendations- Recommendations on the applicability of the device in achieving its intended function subject to the criteria of Section 2 are optional but encouraged.

CONCLUSIONS

The present dissemination of rehabilitation technology is limited in part by poor communication channels and uneven evaluations dominated by anecdotal self assessment by device developers. Improvement in device evaluations will be facilitated by the adoption of a standardized evaluation methodology such as that outlined here.

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A CASE STUDY IN TECHNOLOGY TRANSFER: DESIGN AND DEVELOPMENT OF A HYDRAULIC FORCE TRANSMISSION SYSTEM FOR BODY-POWERED UPPER-LIMB PROSTHESES

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ABSTRACT

A technology transfer methodology developed and followed by NASA has been implemented in an ongoing project to replace the current cable control systems of body-powered upper-limb prostheses with a hydraulic force transmission system that can be packaged inside the prosthesis. NASA expertise in hydraulic control has been identified and a prototype device has been built. The technology transfer process is most effective when a needs driven approach is used; the participants have a strong commitment to, and become champions in, the project's outcome; there is active involvement by a technology transfer agent; and person-to-person interactions are incorporated.

INTRODUCTION

The NASA Technology Utilization (TU) Division assists private companies, associations, and government agencies to make effective use of NASA's technological resources to improve U.S. economic competitiveness and to provide societal benefit. As part of this program, NASA contracts with the Research Triangle Institute (RTI) to operate a Technology Applications Team. The Team works actively with private and public sector organizations to conduct Applications Engineering Projects for transferring NASA-developed technology into new, commercially available products for people with disabilities. NASA and the Technology Applications Team have developed and follow a phased methodology for technology transfer in rehabilitation (1). This paper illustrates how the NASA technology transfer methodology is being implemented in an ongoing project to design and develop a hydraulic force transmission system for body-powered upper-limb prostheses.

THE NEED

It is estimated that there are approximately 100,000 upper limb amputees in the United States and that 50 percent of these wear some type of prosthesis. Of the 50,000 persons who wear prostheses, approximately 90 percent use a body-powered device while only 10 percent use an externally powered device. The technology used in body-powered prostheses has not changed significantly since being developed during and shortly after World War II. Shoulder harnesses and cable force transmission systems are still used to activate the prehensor mechanism.

The Children's Hospital at Stanford (CH@S) is currently being supported by the National Institute on Disability and Rehabilitation Research (NIDRR) to improve body-powered upper-limb prostheses. As part of this project, Mr. Maurice LeBlanc at CH@S is investigating the feasibility of replacing the cable system with a hydraulic control system that can be packaged inside the prosthesis. Work completed by Mr. LeBlanc has resulted in functional requirements for a hydraulic force transmission system for body-powered upper-limb prostheses (Figure 1).

- Master actuator on upper arm cuff—½ inch to 1 inch protrusion maximum
- Slave actuator in wrist section—2 inches in diameter and 2 inches in length maximum
- 90% efficiency for system
- Powered in one direction with spring return
- Capable of 60 pounds force and 2 inches excursion (120 inch-pounds of work)
- Variable force and excursion with rated work capacity (desirable)
- Light, leak-free, hygienic
- Self-contained inside the prosthesis to operate a prosthetic prehensor

Figure 1. Functional Requirements for Hydraulic Force Transmission System.

APPROACH

The NASA Technology Applications Team was asked by Mr. Joseph Traub at NIDRR to assist CH@S in identifying pump and fluid handling technology that would meet the requirements as described above. The Team first conducted a thorough search of the literature to identify any related products that might be commercially available. Although no exact technology match was found, the Team was able to identify FCD Corporation of Hamden, Connecticut, as a leader in the development of applied miniature pump technology. Maurice LeBlanc then met with engineers at FCD. However, their subsequent design failed to meet some of the performance characteristics and physical dimensions as specified in the requirements and further work with the company was not pursued.

The Applications Team then prepared a Problem Statement describing the problem and functional requirements for a solution and distributed it to the Technology Utilization Officers at each of the nine

NASA Field Centers. Two responses to this technology request were received from Johnson Space Center (JSC) in Houston, Texas. A preliminary assessment of these by Mr. LeBlanc indicated that the Propulsion and Power Division at JSC had the best conceptual design. The Team helped arrange a meeting on May 27, 1987, between Mr. LeBlanc and NASA engineers to have Mr. LeBlanc explain in person the unique challenges facing the development of a hydraulic control system for body-powered prostheses. This meeting proved very beneficial and Mr. Paul Svejkovsky at NASA JSC, with support provided by Mr. Richard Bozeman, began working on a "as have time" basis to design and build a prototype system.

To date, a rough prototype hydraulic force transmission system has been built by Mr. Svejkovsky and it was demonstrated with favorable review at a project Advisory Group meeting held at CH@S on November 7, 1987. This system includes a quick disconnect wrist, a bellows body pump, a bellows prehensor actuator, and an alternate body pump that can be used to supplement the regular one. Design of the master actuator, or body pump, and the slave actuator located in the wrist section remain the biggest challenges to developing a system that could replace current cable operated devices.

The NASA Technology Applications Team at RTI with assistance from CH@S and JSC is preparing a project plan for further design, development, and evaluation of the hydraulic force transmission system. Support for this project is being provided by NASA, NIDRR, and CH@S. In addition, a leading U.S. manufacturer of upper-limb prosthetic components has observed the prototype developed by JSC and has expressed interest in the outcome of this project. The Applications Team will continue to serve as an active transfer agent in the project by coordinating further development efforts and by helping to commercialize the system.

DISCUSSION

An active technology transfer methodology developed and followed by NASA has proven most effective when certain, key ingredients are present. These are when a significant problem area is identified; there is potential for commercial success, e.g., the transfer is needs driven; the target population is well-defined; functional requirements for a solution can be specified; applicable technology or expertise is identified; there is manufacturer interest; there is a commitment by the participants to champion the project through to its conclusion; and there is involvement by a technology transfer agent. In an active approach, the technology transfer agent is not merely supplying information, but rather is actively participating in the application of the technology to help solve the problem (2).

The project to develop a hydraulic force transmission system for body-powered upper-limb prostheses illustrates each of these ingredients. The need for improved body-powered prostheses is widely recognized and work by CH@S has shown that an improved prosthesis would be an attractive commercial product for arm amputees. The target population has been defined as upper-limb amputees, with below-elbow amputees being the first group considered. CH@S has specified to the extent possible functional requirements for a proposed solution. The technology and the expertise necessary to develop a hydraulic control system have been identified at NASA. At least one manufacturer has expressed interest in this project and others are being kept informed of the progress. Finally, this project has been fortunate to have support from four seperate organizations, with the NASA Applications Team at RTI acting as the active transfer agent.

The role of a technology transfer agent in rehabilitation technology transfer cannot be overemphasized. Initially, an active approach should be used by the agent to identify technology resources and to bring them together with the problem originator, most desirably through person-to-person interactions. The transfer is unlikely to take place through information exchange alone. As the project matures, the likelihood of success increases if the technical expert becomes, in part, a champion in the project's outcome as well. His or her commitment to the project is essential to the actual transfer, or application, of the original technology or expertise to the new area in which it will be used. The technology transfer agent should also assume some of the responsibility for identifying funding sources during research and development and for interacting early on with manufacturers who may be interested in commercializing the final product.

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COMMERCIALIZATION IN THE STRATEGY TO DEVELOP THE CANADIAN MEDICAL DEVICES INDUSTRY

HILL, S.

A Federal-Provincial initiative is currently underway to vitalize the Canadian medical devices industry. One task of this initiative is to examine the relationship between industry and the research community in the commercialization of new and applied technologies. The objective is to develop strategies and mechanisms to facilitate this process.

Background

In May 1987 at a conference of Ministers responsible for Federal/Provincial Procurement, it was agreed that a Task Force on Canadian Source Development would examine ways to increase Canadian Value-Added in the medical devices industry. A working group was formed to address several areas of action. A Sub-Committee on commercialization was subsequently struck. This paper focuses on their work addressing commercialization of the medical devices industry.

The medical devices industry was targetted for several reasons. An estimated 75% of health care requirements are currently produced outside Canada. At the same time Canada has in place the basic infrastructure to support such an industry. Our research and development facilities, manufacturing capabilities and health care delivery systems are all world class. The medical/clinical communities have indicated a commitment to supporting an indigenous industry. Such support, as researchers and consumers is essential to the success of this effort.

Canadian medical Devices Industry

The Canadian medical devices industry is characterized by a number of large multinationals and many small and medium sized firms. The larger corporations are generally Canadian subsidiaries of multinationals which assemble imported parts and supplies. Many are exclusively distributors. Virtually none of these subsidiaries have a mandate to develop and produce their own products. Thus, the commitment to R & D. in Canada is low.

A 1979 survey showed that most Canadian owned companies are small with fewer that 50 employees and sales less than 5 million annually.(1) These companies address specific market niches with narrow product lines. Because the domestic market is small they must pursue export markets. Most lack the financial resources and facilities to conduct in-house development of future products. Yet future product development is critical to the survival of these small corporations whose present niches have a limited life.

Research & Development Environment

In recent years a growing commitment to developing closer ties with industry has been generated within the research community. Governments have supported these efforts through the creation of technology transfer foundations associated with post secondary institutions in most provinces. Within Ontario seven Centres of Excellence have recently been established to stimulate advanced research, in association with private sector firms. Even "traditional" public sector funding sources such as the Medical Research Council have mounted research programs premised on indust- rial university cooperation.

Current Initiatives

A major task in the initiative is to develop the necessary linkages within the commercialization process. The strategy must include measures to encourage increased investment into developing the industry. To achieve this several issues must be addressed.

The first is marketing. Under the current model, R & D is conducted to address clinically-based needs with academic objectives (i.e. the the validation of a concept).

Most often this involves the assessment of an initial prototype. At this stage industry or investors are approached and factors determining commercial viability are addressed.

Industry decisions are guided by market considerations. Securing the necessary market information is usually beyond the researcher's mandate, expertise or available funding. Without this information, it is difficult to interest industry or investors. Designs which are picked up must inevitably be redesigned to fit the application, product line and manufacturing capabilities. Thus, technology transfer is not a smooth continuum rather, it involves a radical shift in objectives and design.

For those projects in which commercialization is clearly the objective, incorporating industrial requirements at the initial stages of development offers a greater chance for successful transfer. That is, the process must be market driven.

Once a product is ready for market, distribution channels must be accessed. Because Canada's domestic market is small, export marketing is essential. One approach for small firms is to link into the distribution networks of larger multinationals through marketing arrangements. A second avenue involves the development of an export consortia. Discussions are currently underway among distributors to explore this approach.

Networking mechanisms will contribute to successful commercialization. Whether formal or informal; they can facilitate the linkages between development groups, investors, and manufacturers. They also serve to disseminate information. For the most part industries, especially small to medium-sized, are not aware of the innovations emerging from research laboratories; nor is the research and development community attuned to the priorities and needs of industry.

The role of government is to create an environment which is conducive to the healthy growth of the industry. Researchers', manufacturers' and investors' needs must be supported. The mandates and criteria of existing funding structures are being reviewed to determine where the funding gaps exist. Other possible measures include tax incentives for investors. Governments can also play a role in networking. An inventory of developments within the research community has been compiled through an extensive survey. The information is being applied to this end.

Interviews have been held with industries to determine their commitment and perceived role in assisting the intitiative. Global product mandating, potential marketing arrangements as well as the increased purchase of Canadian-made components have been discussed with the multinationals.

The goals of the Task Force are to strengthen the medical devices industry, to broaden the manufacturing base and create quality employment.

Millions of public sector dollars are annually spent on research and development. New designs with commercial viability are most commonly licensed to multinationals outside Canada. It is therefore an objective to have the products of these research dollars reinvested into the economy which funded the original work.

There are similar benefits to the R & D community. Revenues from successful commercialization can be applied to sustain future research endeavours. This can occur directly through royalties and licensing fees, or indirectly through corporate profits reinvested into further research and development. Successful commercialization also serves to fulfill the developers' original motivations; that of fulfilling the clinical needs originally identified.

Conclusions

Work in the following months will focus on the development of strategies and mechanisms to address the issues. Specifics of the resulting program will be discussed at the conference.

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THE JOB ACCOMMODATION NETWORK: A System That Works

Barbara T. Judy and Michael J. Brantmayer

One degree of success is realized when a project which was once a dream comes into being. Real success is experienced when that project continues to exceed expectations four years later. These statements more than accurately describe the Job Accommodation Network (JAN). The brainchild of two prominent businessmen, JAN has evolved into a national information and consulting service whose mission is to assist employers and rehabilitation professionals in the hiring, retention, or advancement of persons with disabilities through job accommodation.

The JAN network is composed of three main subsystems: the information resources, the staff which provide appropriate accessibility to those resources, and the business and rehabilitation communities. The Network contains thousands of accommodation examples that can assist an individual who is functionally limited to perform the necessary tasks of a job. As with any complex system, much of JAN's success is attributable to the qualified personnel who make it work.

JAN has six Human Factors Consultants on staff, each with a different background and approach to making job accommodations. Areas of expertise include those of medicine, rehabilitation, human physiology, statistics, health and safety engineering, ergonomics, and human factors engineering. Included in the specialty areas of experience is a consultant who brings personal and technical knowledge of accommodations for individuals who are blind or visually impaired. Another has many years of experience in the rehabilitation of persons with hearing impairments. An unbeatable team at brainstorming job accommodation situations, they are the heart of the JAN system. It is their essential function to determine what type of accommodation would assist a potential or current employee to perform the tasks associated with a specific employment setting. It is the consultants who must, many times, use their own combined ingenuity to provide a solution to a particularly unique situation.

The term "resources" has been most prevalent throughout the previous discussion. Essential to the continued success of JAN is the sharing of information by businesses who have successfully accommodated a person with a disability and the networking of other resource professionals to reach a common goal. To assure effective and efficient solutions, continuous updating of new and innovative accommodations is an ongoing process.

Discussion of the success of any project would be incomplete without the valued feedback of those who have made use of that project's services. In October of 1986, funding was provided by the National Institute on

Disability and Rehabilitation Research (NIDRR) to conduct an evaluation of the performance of the Job Accommodation Network. The results of this survey were astounding. Of the total number of calls received, more than one-third involved the potential hiring of a new employee. Of this number, 67% were actually hired with the majority of these employers citing JAN information as a critical factor in the decision. Another quarter of the total calls were for accommodations to allow for the retention of a current employee. In 86% of these inquiries, the individual was retained. Even more importantly, in 100% of those instances in which an individual was retained, promoted, or realized an increase in productivity, the information provided by JAN was noted as a significant factor in the final result.

Other interesting outcomes from the survey included answers to questions about how well the information received met the need of the caller. An overwhelming 95% of the respondents said their needs were understood and met by the JAN consultants. When asked if they would consider using JAN again, 98% replied in the affirmative. Another important aspect of any information system such as JAN is whether the caller receives information promptly, and more than 94% of those surveyed answered yes to this question.

The number of calls received at the Job Accommodation Network is steadily increasing at a rate of approximately seven percent per month. If this trend continues, the JAN staff will process over 3,800 calls in 1988 alone. Based on the figures provided by the evaluation survey, it is estimated that over 2,700 persons with disabilities will either be hired or retained in 1988 utilizing information provided by the Job Accommodation Network.

By July of 1988, JAN will have been available to callers for four years. In order to assure its continued service, the Network is seeking sources of private funding. This is being accomplished through the establishment of a private non-profit corporation known as the Job Accommodation Network of America, Inc. or JANA. Its mission is to provide the resources that will enable the Network to function indefinitely. It is through this commitment that the basic services and structure of JAN will not change but will remain a free service.

The policy of the JAN staff is to provide useful and meaningful information to each and every caller to fulfill their purpose of assisting employers in overcoming functional limitations in the workplace for qualified individuals with disabilities.

ADD EQUALS MULTIPLIED POTENTIAL FOR THE ASSISTIVE DEVICES MARKETPLACE

Kenneth G. Reeb, Jr., Electronic Industries Foundation,
Rehabilitation Engineering Center

We have all witnessed remarkable progress within the past decade in the development and delivery of adaptive products to persons with disabilities. Service delivery professionals, such as those that form the nucleus of RESNA, have played important roles in that progress. Of course, there is still much to be done. Although we cannot afford to become complacent, it is nice periodically to take stock of the progress that has been made.

The accomplishments to date, however, would not be nearly so significant if not for the efforts of private, for-profit companies who develop, produce and market commercial products for persons with disabilities. It is really the partnership between product companies and service providers that has been fundamentally responsible for successful technology transfer. Commercial products, for example, are used routinely by medical, rehabilitation and educational professionals to help meet the needs of their clients. Likewise, product companies deliver more than just devices. They provide support in such vital areas as needs assessment, training and maintenance/repair. Companies have demonstrated an effectiveness in meeting needs for technology at a national level, with the service delivery network better suited for addressing needs at the local level.

In October of 1987 a trade association was formed comprised of companies that manufacture and market assistive products to elderly and disabled individuals. This association has the potential for accelerating the rate of progress in the development and delivery of technology by leveraging the already substantial capabilities and energies of the commercial sector. It provides an opportunity for companies to organize and to pursue strategies collectively that are otherwise difficult, if not impossible for any single company to tackle.

This new organization is the Assistive Devices Division (ADD) of the Electronic Industries Association (EIA). EIA is the oldest and largest full service national trade organization representing the entire spectrum of companies involved in the manufacture of electronic and electronic-related products and systems. Aligning with EIA provides ADD with valuable structural support while assuring the division the autonomy to pursue its unique objectives. The new division was formed in large part due to the support and encouragement of the Electronic Industries Foundation Rehabilitation Engineering Center (EIF/REC).

The principal goal of the Assistive Devices Division is to develop the marketplace for assistive devices. That goal will involve the following objectives, as formulated by ADD members in October, 1987:

- To present division positions to and serve as a resource and an information source for the media, other EIA divisions, government bodies, consumers and consumer groups, standards-setting bodies, and other organizations.
- To conduct public-service and communication campaigns aimed at increasing public awareness of the availability of technological solutions to the needs of persons with disabilities.
- To survey consumer needs and conduct demographic studies.
- To facilitate communication and technology transfer between developers and manufacturers.

- To explore regularly the marketplaces of the future.
- To provide support, encouragement and assistance to educational efforts in this field.
- To collect and report on industry data in such a manner that the proprietary nature of data supplied is fully respected.
- To encourage development of alternative means of product financing.

A division Board of Directors has been elected, which is comprised of representatives from private sector member companies. ADD currently is developing a committee structure. Committees will serve as the backbone of the division, since they will be responsible for developing and pursuing action plans aimed at accomplishing the division objectives. Each committee also will consist of representatives from private sector companies, with staff support being provided by Larry Scadden and Ken Reeb of the EIF/REC. As committees are formed and become active, there will be many occasions for interaction and collaboration with RESNA, through its committee and SIG structure. As of this writing, EIA/ADD membership includes the following companies:

- Apple Computer
- Applied Concepts Corporation
- Artic Technologies
- AT&T
- ComputAbility Corporation
- IBM Corporation
- Kurzweil Applied Intelligence
- Kurzweil Computer Products
- Optelec U.S., Inc.
- Phonic Ear
- Prentke Romich
- Sonic Alert
- Street Electronics Corporation
- Telesensory Systems, Inc.
- VTEK
- Williams Sound Corporation

An active recruitment drive is underway and plans are being made for a division meeting to be held as part of EIA's semi-annual conference in Washington, D.C. in April, 1988. These activities promise that dynamic changes will occur between the time of this writing and the RESNA conference. A poster session is planned in order to update interested RESNA members.

In sum, this is an exciting development in the field of rehabilitation technology. The Electronic Industries Association's Assistive Devices Division provides opportunities for combining, augmenting and channeling commercial company resources toward objectives intended to ensure that increasing numbers of persons with disabilities benefit from the available products of technology. In the past, commercial companies have proven to be effective in developing and delivering assistive products. EIA/ADD promises to heighten that effectiveness in the future.

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COMMERCIALIZATION, A NATURAL EXTENSION OF TECHNOLOGY TRANSFER

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The obvious interrelationship of research, development, manufacturing, marketing and acquisition begs for increased cooperation between researchers/developers and vendors to make available more commercial rehabilitation aids and devices to persons who may benefit from their use. This is a premise the author suggests will be helpful in moving more products from the laboratory and into the "hands" of more users.

A conceptual model of the technology transfer and commercialization activities is presented (see figure 1) to increase the understanding of the process and its interrelated parts. This simple model starts with an idea or concept, and traces the major steps required for success in providing a product to users with disability.

The model has three stages of activity. First is the research and development stage where science is applied to an idea or an identified need and results in a prototype device. The second stage is the commercialization process. It starts with the contacting of potential manufacturers and ends with a commercial product ready for distribution. The third stage is the acquisition and use parts of the process. It starts with marketing and ends with a satisfied user.

A number of conceptual models describing the process (Reswick, 1985; Ferguson-Pell, 1983; Bernett, 1987; Trachtman, 1987) have been developed. This model differs from those preceding it in two ways. It expands the commercialization activities highlighting the

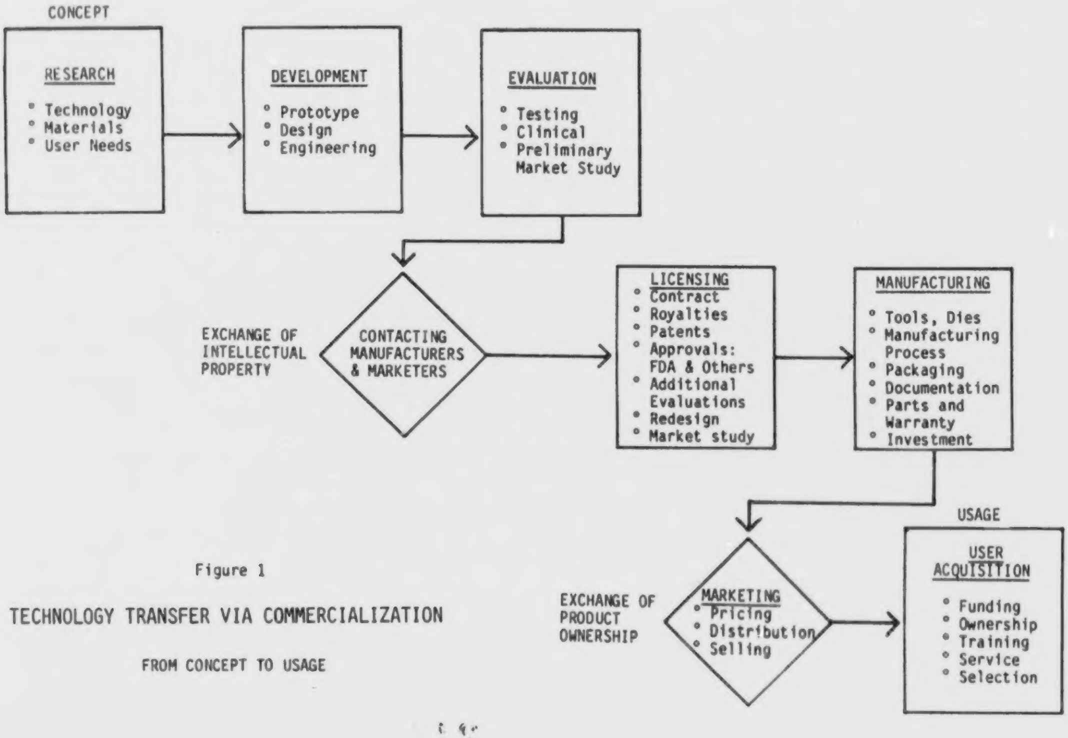
CONCEPT
RESEARCH
° Technology
° Materials
° User Needs
DEVELOPMENT
° Prototype
° Design
° Engineering
EVALUATION
° Testing
° Clinical
° Preliminary Market Study
EXCHANGE OF INTELLECTUAL PROPERTY
CONTACTING MANUFACTURERS & MARKETERS
LICENSING
° Contract
° Royalties
° Patents
° Approvals: FDA & Others
° Additional Evaluations
° Redesign
° Market study
MANUFACTURING
° Tools, Dies
° Manufacturing Process
° Packaging
° Documentation
° Parts and Warranty
° Investment
EXCHANGE OF PRODUCT OWNERSHIP
MARKETING
° Pricing
° Distribution
° Selling
USAGE
USER ACQUISITION
° Funding
° Ownership
° Training
° Service
° Selection

Figure 1

TECHNOLOGY TRANSFER VIA COMMERCIALIZATION

FROM CONCEPT TO USAGE

exchange of intellectual property and it adds the marketing and user acquisition activities which highlight the exchange of product ownership. These two critical exchange points are noted on the model as diamond shaped boxes.

The commercialization work of the Electronic Industries Foundation's Rehabilitation Engineering Center has identified these two exchange points as the areas where many of the breakdowns occur within the technology transfer/commercialization process. A clearer understanding by the inventor/developer of the problems encountered by the manufacturer/marketer may alleviate some of the frustrations expressed by developers as they try to have their prototype devices seriously considered for commercialization.

Institutions which do R&D that have a successful record of commercialization of their prototypes, for the most part, have established good working relationships with companies that manufacture and market products within their areas of interest. Conversations with both researchers and manufacturers who have worked together indicate that this cooperation results in better products in shorter time and with less development cost. These working relationships enhance the licensing and manufacturing processes that follow.

Inventors and developers need to have some appreciation of the marketing problems that effect the exchange of ownership process. Our experience has shown that market demand for a device is far more indicative of a successful product than device usefulness. Communication and understanding by all of the participants in the technology transfer/commercialization process is important so that more products may be made available to those who need them. After all, isn't this what it is all about?

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"SPECIAL INTEREST GROUP". 8

Sensory Aids

Aide sensorielle

QUESTIONNAIRE RESPONSES RELATING TO EMERGENT TECHNOLOGY: DESIGN/OPERATIONAL FEATURES OF BLIND READING AIDS

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ABSTRACT

The project entitled *Design/Operational Features of Portable Blind Reading Aids*, has used (1): technology surveys to identify potentially useful components as candidate technologies for inclusion in a next-generation reading aid; and (2) telephone questionnaires of blind individuals to determine the likely degree of success of approaches using these components, based on their currently perceived needs and preferences. This report describes some candidate technologies, and presents the responses of several technologically sophisticated users to question relevant to the items. A discussion follows, offering some preliminary interpretation of results to date.

INTRODUCTION

An earlier questionnaire has revealed a widely perceived need, among visually impaired persons, for a more powerful, flexible, and convenient reading aid[1]. Such interviews have also documented attitudes toward certain matters of practical importance, such as cost and weight[2]. Responses from interviewees have allowed us to begin selecting candidate features for incorporation into a final device[3]. That such an aid is widely needed is beyond dispute: it is estimated that 500,000 individuals in the U.S. are *totally blind*, including perhaps 50,000 veterans; up to 1.5 million Americans are visually impaired, including perhaps 200,000 veterans[4].

METHODS

In order to identify and verify promising candidate technologies for use in a next-generation reading aid, we have researched emergent technologies, with an eye to matching them with identified needs of blind interviewees. At the same time, we have been administering a series of questionnaires to visually impaired persons to probe their wants and needs in this area[1,2]. One questionnaire, which is reported on here, focuses on the views of visually impaired individuals who have relatively extensive (> 1 yr) experience with technology (e.g., Optacon, KRM, adapted computer). Interviewees have been queried, among other things, on their reactions to the capabilities that new technologies could deliver. This questionnaire is detailed: its administration takes between one and two hours, and answers are open ended. Content analysis of responses of the first eight of approximately two dozen interviewees are reported and discussed below.

INTERVIEWEES

Interviewees were selected at random from participants in our previous questionnaire[1] who were identified as being technologically experienced. Interviewees met this criterion if they had at least one year of experience on any technology-based assistive reading device, (e.g., the Optacon, the KRM, adapted computer). As it turned out, *all* eight had significant experience with adapted computers; seven had significant experience with the Optacon, while five were competent on the KRM. The most common adaptation, predictably, was the addition of speech output (all 8); the next most common adaptation was the addition of a Versabraille (3); one interviewee also had a special keypad added to his system. The most widely used application was word processing (7); three used the computer for data base management, one for telecommunications, and one for programming. On the whole, these interviewees used the computer primarily to increase productivity on the job.

CANDIDATE TECHNOLOGIES

- *TransImage 1000*

TransImage, a start-up company in Mountain View, CA, has recently brought the TransImage 1000 to market[5,6,7]. It comprises a camera which is manually scanned over lines of text, a board which plugs into an expansion slot on an IBM-compatible Personal Computer, and software. This package captures text optically, identifies individual characters using computer text recognition techniques, and inserts them automatically into applications running on the PC. With appropriate custom software and hardware, this device could provide audio or tactual feedback that allows a visually impaired person to enter text into a portable IBM PC (which can also be equipped with a speech synthesizer). In this hand-scan configuration, the device can provide portabity. Another option is to trade portability for automatic scanning capability, by attaching the PC to a printer-sized peripheral. One PC might be configured to support both options.

- *Alternative controllers for text editors*

Currently, visually impaired individuals typically control text editors on their computers from the keyboard. Several new devices which may allow enhanced performance are now possible. Four representative ones were included in the survey, and are briefly characterized below. One is the use of a standard Apple Macintosh-style "mouse", which could be modified to allow a user to navigate through text with tonal feedback indicating position of lines and text. The second is a tablet which sits atop a table and allows a person to specify position on the screen, while receiving some spatial and layout information tactually. The third is a special bar that rotates and slides, which is added to a standard keyboard beneath the space bar to provide the user mouse-like cursor control, but without the necessity of lifting one's hands from the keyboard; like the mouse, it can be provided with tonal feedback to assist the user in orienting to the text. The fourth device is a foot pedal which sits on the floor and allows the user to move a cursor around text under foot control, with tonal feedback. Our questionnaire contained items probing responses to each of these devices.

RESULTS

- *Responses to TransImage handscanned-type capabilities*

In response to a question asking whether they would like a personal computer to be able to recognize print material and insert it in applications, all eight respondents emphatically answered in the affirmative. Seven of the respondents wanted the text to be scanned automatically, while one was not certain on this point. Five of the interviewees indicated a desire also to be able to hand-scan a page, while two were negative on this point and one was uncertain. Respondents were rather more evenly divided when questioned on the particulars of implementing automatic scanning. In response to a question on whether an automatic scanner requiring manual feed of each page individually was acceptable, three answered positively, three answered negatively, and two were uncertain. In response to a follow-up question on the whether they would want an automatic scanner which could handle stacks of pages printed on one side, four answered positively, three negatively and one was uncertain. All eight thought that it would sometimes be important to be able to scan bound materials as well, and would be willing to turn pages. Four wanted the device to handle bound materials fully automatically, including turning pages; but three declined this option, citing probable high cost; and one was uncertain.

- *Responses to special cursor control devices*

Responses here were quite mixed. Five of the respondents like the idea of using the mouse to assist with text navigation and manipulation, while three did not. The response was just reversed for the table-top tablet and the roller-bar cursor controllers: three voiced their approval, while five responded negatively. The interviewees were much less certain about the use of a foot pedal: while two responded favorably and two negative, the remaining four said that they were not certain, and would need to gain experience with the approach.

DISCUSSION

Some interesting preliminary inferences can be made from the these answers. The first is that blind individuals with technological experience appear to appreciate the power delivered to them by the personal computer. All respondents have gravitated in that direction, regardless of their first device, making the computer the only device which they all had in common. The second is that hand-scanning capabilities and automatic scanning for text acquisition are seen as complementary, rather than mutually exclusive, capabilities. The third is that blind individuals have more limited and more disparate experience with alternative devices for dealing with text manipulation; they appear to be judging by analogies which are often only partially appropriate, and which additionally carry individual judgements in different directions.

CONCLUSIONS

In conclusion, results to date indicate that visually impaired persons appreciate the leverage which technology can give them, particularly in making themselves competitive in the workplace. They strongly endorse efforts to facilitate access to print material, wanting for the most part both automatic scanning and hand scanning. They are less certain precisely how technology might assist them in manipulating text once it is acquired, but will consider a range of alternatives that can be made available.

ACKNOWLEDGEMENTS

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EFFECTS OF STRUCTURAL AND PSYCHOLOGICAL CHARACTERISTICS OF LETTER GROUPINGS IN **OPTACON** READING BY THE BLIND

Eugene C. Lechelt

As most information storage and retrieval are based on printed materials, the visually impaired have essentially no access to them. Hence it is critical that we understand the processing of printed material in the tactile modality. In the studies reported we examined how the blind discriminate individual letters, presented tactually, as well as letter sequences varying in frequency of occurrence and words varying in psychological dimensions.

METHOD

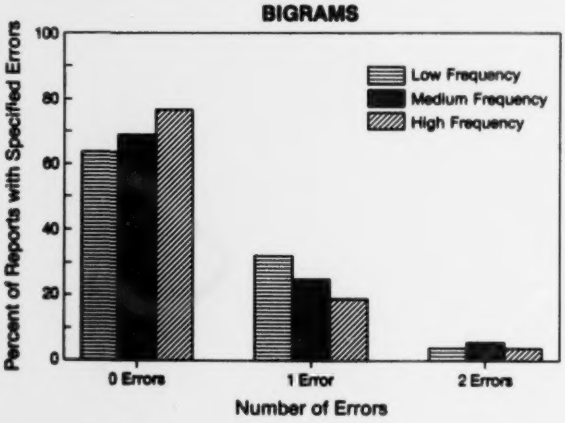
Five highly skilled blind OPTACON users participated in each of the studies. An OPTACON was used to present IBM standard gothic sans serif upper-case letters to the tactile array on which each observer rested his/her left index fingertip. A custom designed apparatus system was used to provide computer controlled rates of stimulus presentation beneath the OPTACON camera. Letters occupied, i.e., stimulated, the central 20 rows of the OPTACON tactile array. The intensity level was set by each observer to be at a comfortable level. White noise was presented binaurally to mask sounds emitted by the tactile array. A scan mode of presentation was used in which letters moved across the tactile array from right to left. Pilot studies determined that a presentation rate of 4 mm/sec was optimal.

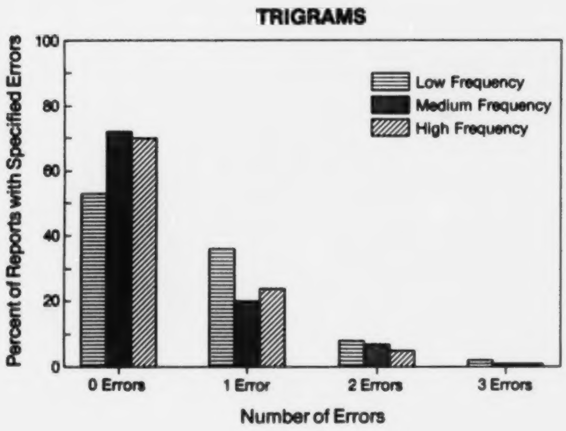
For the letter recognition experiment 15 random sequences of the alphabet were presented and observers were asked to report each letter. The second series of studies involved the recognition of three types of letter sequences: bigrams, trigrams and four-letter words. For bigram and trigram presentations, participants received a letter set and were asked to identify each letter. For word presentations, they were asked to identify the word or, as many letters as possible. Participants were told if they were correct or what an incorrectly identified letter/word was. Bigram and trigrams of low, medium, and high frequency rates of occurrence in print were selected (3). Fifty in each frequency range were presented in random order. Words were chosen according to high and low ratings on 3 dimensions: (1) concreteness (C), the extent to which the word refers to concrete objects that can be seen, heard, felt, tasted or smelled, (2) imagery (I), the extent to which the word can arouse mental images of things or events, and (3) familiarity (F), the extent to which the word is commonly or frequently experienced (4&1). As concreteness (C) and imagery (I) are highly correlated (4), these dimensions were combined in the present study. A completely crossed design was used to determine categories of words. Four categories were used: High F, High CI; High F, Low CI; Low F, High CI; Low F, Low CI.

RESULTS

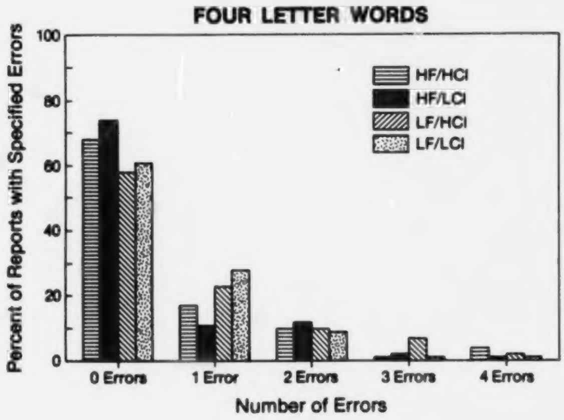
Letter Recognition: Accuracy of individual letter recognition was very high ($\bar{x}$ = 93%, S.D. = 6%). An examination of the confusion matrix shows that the small number of errors made can be accounted for, almost totally, on the basis of the structural similarities of letters, e.g., "M" and "N".

Bigrams and Trigrams: Both bigram and trigram recognition reports, averaged across observers, showed a "frequency effect", i.e., recognition accuracy generally increased as a function of the familiarity of the letter sequences.





Four-letter words: Surprisingly, familiarity (F), and concreteness (C)/imagery (I) did not affect appreciably the recognition of four-letter words varying across these dimensions.



DISCUSSION

The letter, bigram, and trigram data are in agreement with studies using similar stimulus material presented to the visual modality; however, the four-letter recognition data are somewhat inconsistent. Researchers (2) have shown word imagery is a critical variable in distinguishing between how the blind and sighted learn words. It may be that "psychological dimensions" of words are less likely to influence their immediate recognition when presented tactually compared to visually because of inherent modality differences in stimulus processing. Vision is uniquely capable of processing spatially extended stimulation essentially simultaneously, while tactile stimulu processing is successive and integrative over time i.e., the perceptual unit for tactile processing is both spatially and temporally much more restricted. What the visual modality is able to "comprehend at a glance" requires much more processing time in the tactile mode to achieve equivalent perceptual salience.

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DEBUNKING A MYTH: CAN VISUALLY IMPAIRED PERSONS COMPREHEND ACCELERATED SPEECH BETTER THAN SIGHTED PERSONS?

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INTRODUCTION

Perhaps the greatest application of accelerated speech lies as either a print substitution or print enhancement aid for visually impaired persons. According to Wood, many educators consider the aural presentation of text to be the only viable alternative such individuals have to receive academic instruction at the rate demanded by today's schools, (1). Given that the 'normal' oral reading rate is only 180 words per minute (wpm) compared to the average reading rate of 300 wpm for fully sighted readers, the ability to accelerate aurally presented text is important if visually impaired persons are to keep pace with their sighted peers.

The most popular methods of accelerating oral readings on tape are variable speed and time-compression. One of the disadvantages of such taped readings is that there is usually a delay in access time while the desired text is being recorded by a human reader. It is quite possible that in the not too distant future, all books and journals will be recorded directly onto computer diskettes, so that individuals unable to easily access print will be able to listen to the information presented by computer-generated speech.

Researchers and educators have suggested that visually impaired persons are superior in the comprehension of natural speech presented at accelerated rates, relative to their sighted peers, (2,3). While research into the perception of synthetic speech is growing, very few studies have involved visually impaired persons as subjects. Without comparative research, one can only speculate as to whether the superiority of visually impaired persons actually exists. Such research might aid designers of speech synthesis systems for the visually impaired in determining the appropriateness of parameters that may have been established based on data collected using sighted subjects only.

A primary objective of this research, then, was to test the hypothesis that visually impaired persons would be better able to comprehend both accelerated natural and synthetic speech than would sighted persons.[1]

METHOD

Subjects.

Ten visually impaired subjects (4 males and 6 females) and ten sighted subjects (5 males and 5 females) participated in this study. The groups were matched for age and level of education. The average age of the visually impaired subjects was 35.4 years, while the average age for the sighted subjects was 32.3 years. Most subjects were in the process of completing or had recently completed an undergraduate degree. Six of the visually impaired subjects had partial vision, while the other four had some light perception. Four of the visually impaired subjects relied on enlarged print as their primary means of obtaining information, four relied on voice only, and two made use of both braille and voice. Five of the visually impaired subjects were experienced in listening to synthetic speech (i.e. at least three 1 hour sessions per week for the last 6 months). None of the sighted subjects had such experience. All subjects had normal hearing, and all listed English as their first language.

Test Material and Equipment.

Subjects were asked to listen to a number of short expository passages (each 200 words in length). Three stimuli voices were selected: a human (male) voice compressed using a General Electric TCS; the CallText 5050 (a dedicated text-to-speech voice synthesizer by Speech Plus Inc.); and the MacinTalk voice (a text-to-speech software package for the Apple Macintosh computer). The presentation rates for the test passages were calibrated to correspond with those of 150, 200, and 250 wpm as presented by the CallText 5050. All stimuli were recorded from source onto a master tape, so that the order of the test passages could be randomized for each subject.

Procedures and Measures.

After completing a short interview concerning the subject's exposure to accelerated speech, and a hearing test, each subject was exposed to seven familiarity passages followed by a pre-test passage presented at a normal oral reading rate (180 wpm), two sets of nine test passages, and a post-test passage (180 wpm). Each passage was followed by a series of pre-taped questions which included: asking the subject to estimate the percentage of the passage that was understood (ESTIMATED UNDERSTANDING); and to briefly answer five open-ended questions concerning the content of the passage (CONTENT QUESTIONS). Subjects gave a verbal response to all questions.

RESULTS

The experiment was a mixed 2X3X3X2 factorial (GROUP X VOICE X RATE X SET). An analysis of the pre-test/post-test data was performed to measure any learning that might have occurred as a result of familiarity with the test procedures. Three-way ANOVAs with subjects nested within GROUP did not reveal any significant interactions or main effects for the measure ESTIMATED UNDERSTANDING (EU). However, for the measure CONTENT QUESTIONS (CQ) a main effect was found for GROUP, ($F(1,18) = 8.83$, $p<.01$). Averaging the two tests, sighted subjects ($X=70.5\%$, $SD=22.1$) scored higher than did the visually impaired subjects ($X=49\%$, $SD=18.6$).

When analyzing the data for the main test passages, the three-way interaction of interest is GROUP X VOICE X RATE. This interaction did not prove to be significant for the measure EU, but was significant for the measure CQ ($F(4,72)=4.32$, $p<.025$) The means recorded in Table 1 are presented graphically in Figure 1. The sighted subjects scored higher on the content questions than did the visually impaired subjects, for all experimental voice by rate combinations.

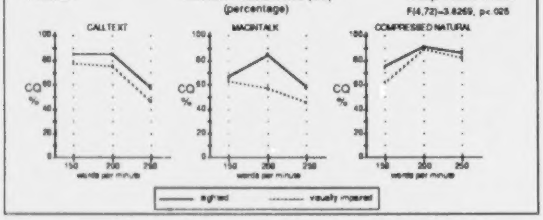
TABLE 1 MEANS - CONTENT QUESTIONS (GROUP X VOICE X RATE)*

		CALLTEXT		MACINTALK		COMPRESSED NATURAL	
	RATE	MEAN	SD	MEAN	SD	MEAN	SD
Visually Impaired	SLOW	77.5	(13.33)	63.3	(19.21)	61.5	(25.81)
	MED	75.5	(24.81)	57.0	(28.30)	89.0	(10.21)
	FAST	46.5	(23.23)	45.5	(29.47)	82.0	(19.36)
Sighted	SLOW	85.0	(19.60)	66.8	(14.35)	75	(17.92)
	MED	85.0	(20.13)	84.5	(17.91)	91	(12.52)
	FAST	58.0	(17.05)	58.5	(20.84)	86	(12.73)

*$F(4,72)=4.32$, $p<.05$

FIGURE 1 CONTENT QUESTIONS (CQ) (percentage)

Group x Voice X Rate $F(4,72)=3.8269$, $p<.025$



DISCUSSION AND CONCLUSIONS

The popular thought that visually impaired individuals can listen for comprehension better than persons with normal vision, especially at accelerated rates, is not supported by the findings of this study. While there was no significant difference between the groups when subjects were asked to subjectively estimate their own understanding of the passages, the more objective measure of answering content questions indicates that the visually impaired subjects' level of comprehension was lower than that found for the sighted subjects. These findings held for the compressed natural and the two synthetic voices, and across the accelerated rates tested. Since the two groups were matched for level of education, it is unlikely that the superior performance of the fully sighted subjects is due to a difference in intellectual potential. It is more likely that the two groups differ in their methods of storing and retrieving information.

Further research is necessary to determine whether the poorer comprehension exhibited by the visually impaired subjects is due to inappropriate listening skills, underdeveloped skills due to a lack of exposure and subsequent practice with 'text', or a combination of the two. Such information can have implications not only in the area of development of synthetic speech, but also in the manner in which text should be organized (e.g. oral highlighting, repetition of key phrases) so as to maximize the listener's ability to comprehend and recall aurally presented information.

In summary, while the two groups' levels of comprehension seemed to be comparable when subjects were asked to estimate their own understanding of the passages, the sighted subjects scored significantly better on the content questions than did the visually impaired subjects. Researchers and designers should be wary of relying soley on subjective measures for the evaluation of either target population performance or system performance, as such results may not be supported by more objective measures.

FOOTNOTES

[1] For a complete description of the research see: MacGregor, C.G. Comprehension of Accelerated Natural and Computer-Generated Speech By Visually Impaired and Sighted Persons. Unpublished MASc Thesis, University of Toronto, 1987.

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ESTABLISHING PARAMETERS FOR A SCREEN READER

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SUMMARY

Factors used in the design of the SKERFPAD computer monitor screen reader are discussed.

TYPES OF SCREEN READER

Screen readers for blind/visually impaired computer users are generally in one of two categories: the software type that uses keyboard commands to determine what to read from the screen buffer, or a hardware accessory that is independent of the keyboard.

The argument against the latter is that the user must move her hands from the keyboard to access the screen, thus losing "home" position. The problem with software access is that one must learn the hundred or so commands of the access program in addition to those of the applications - and these are sometimes duplicated, to the confusion of the user, particularly a novice.

Until now, most people learning to use computers have been largely concerned with data entry, as in word processing, etc. As vocational uses expand, there will be increasing emphasis on data access - with data entry being a one-time-only event. A clerk who must access an inventory, schedule, etc. need never enter data, so the problem of "leaving the home row" is non-existent. Even people entering data might prefer not learning over 100 commands to read a screen if a means were available that was fast and "intuitive."

THE SKERFPAD SCREEN READER

With input from the staff of the Rehabilitation Engineering Center at Smith-Kettlewell Institute, the SKERFPAD Screen Reader was made to fill these requirements.

A touch-pad a little larger than a typical (12") screen, with raised lines corresponding to the 25 rows on the IBM monitor, permitted instant access to any position. When one touches the pad, the corresponding character (or word) is read by the attached speech synthesizer.

This seems a very "natural" way to read the screen and requires only a few seconds of training ("You're not reading braille - push down very hard").

FUNCTION SWITCHES

The remaining design considerations were what to include as switch options - words/letters, keyboard echo on/off, spell last word selected, speak last few characters typed, and some control over the synthesizer speed. It was also decided to include modes for reading the rest of the line (from the point touched, while touch is maintained), or the rest of the screen (from the point touched, until a "shut up" switch is selected).

In addition to the letters/words modes are a "tones" mode in which a different tone is assigned to each character type (upper-case, lower-case, punctuation, number, space) and a "coordinates" mode where the column and row, rather than the character, are spoken. To assist in locating the cursor in word processing applications, there are switches to read the locations of the voice cursor and the screen cursor.

Another important information channel is the use of bright, inverse, underlined, or blinking attributes for screen characters. The SKERFPAD alters the voice quality to indicate these things.

OVERLAY DESIGN

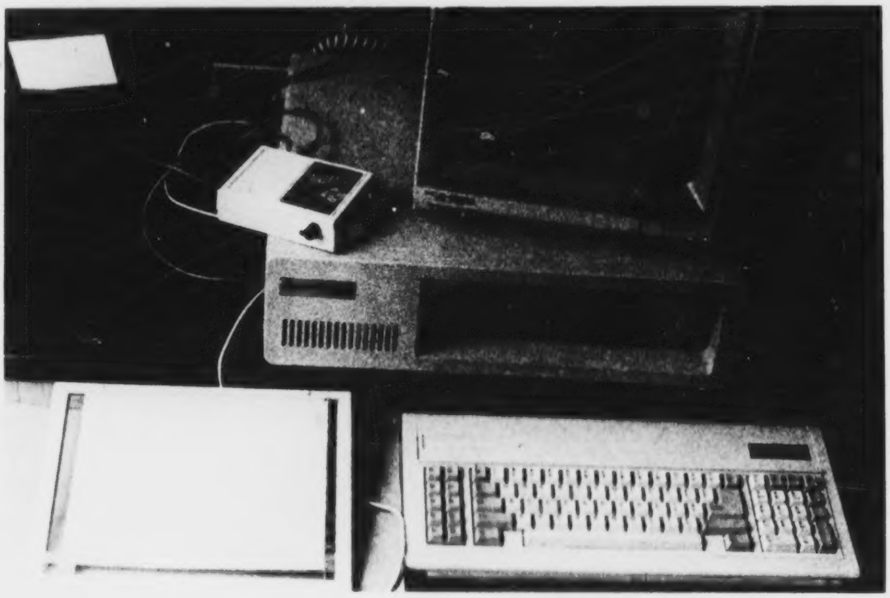
Special consideration was given to the raised overlay placed over the touch-pad to make it as informative as possible for the user. The raised lines used to guide fingers along rows have "bumps" every 10 columns for vertical orientation, and every fifth line is further delineated by a bump in every column. The "switch" areas have braille labels, as do rows 5, 10, 15, and 20.

The functions available from software screen readers that have been (purposely) omitted from the SKERFPAD include search/replace. In general it was decided not to do anything directly affecting the application from the pad. Since it is possible to have the pad and a software access system co-resident, the best of both worlds can be available. If one, for example, wishes to read any new material that comes onto the screen, that function is a typically available one from software readers.

CONCLUSION

The SKERFPAD screen reader was designed to afford access by naive users to IBM computer screens. The goals of minimum training, intuitive command set, and adequate tactile help seem to have been reached. It is economical - actually selling for less than many purely software systems and about a tenth the cost of the best hardware system.

The first reports from users of the system have been very positive and enthusiastic. As expected, the main positive factors are the instant access to any point on the screen, the absence of training requirements, and the correspondence of the pad to the screen. It is anticipated that there will be many more units in use this year, and it should be widely disseminated next year.



"SKERFPAD" Computer Screen Reader for the Blind

Acknowledgments

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HIGH TECH TOYS FOR BACK-TO-BASICS

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INTRODUCTION

Computers and other electronic devices of the age of technology are a mixed blessing. On the one hand they are wonderful tools which assist with both everyday life and specialized activities; on the other hand they carry a strong potential to convert that which is concrete and personal into that which is abstract and remote. For those who are disabled, technology may be beyond remote - it may actually be inaccessible. A strong example of this is the inability of young blind children to use any of the educational software designed for their age group. The information displayed on the monitor - usually colorful, visually appealing graphics - is unavailable to them. Nor can these youngsters hunt and peck their way around the keyboard as sighted children can.

High technology can provide children with advantageous features such as high motivational appeal, flexibility to individualize educational programs in terms of both learning style and level, and the non-human qualities of infinite patience and indefatigability. In an attempt to capture these qualities yet provide a totally accessible, "friendly," and concrete system for blind children, the Smith-Kettlewell Rehabilitation Engineering Center has developed several new educational packages with a novel approach. Each system presents rich offerings to the user by combining features of both tried-and-true, concrete, hands-on manipulative materials with the esoteric electronics of the '80's.

HIGH-TECH TOYS FOR BLIND CHILDREN

Some of the electronic educational materials developed for blind children at the Smith-Kettlewell Rehabilitation Engineering Center are stand-alone units while others require computer interface. All of the systems provide for two-way interaction between the user and the device. This is accomplished by the child's manipulating objects in a meaningful way either spontaneously or in response to a request from the device, and receiving feedback from the system. The feedback may be auditory, (synthetic speech or enjoyable non-speech sounds), tactile, and/or visual (for those users who have some sight). Another feature the systems have in common is modular parts to enhance the flexibility of the manipulatable materials.

The Flexi-Formboard

The Flexi-Formboard is by far the least sophisticated educational toy developed at Smith-Kettlewell in that it is devoid of computer components or interface. It is an electronic formboard (geometric shape puzzle) which is interfaced to a battery-powered animated animal. A variety of such toy animals which move and make noises are commercially available. Because they emit auditory, visual and tactile "signals," and because they are appealing characters, these toys can serve as excellent positive reinforcers for children who are blind, deaf or deaf-blind. Inserting a formboard activates the interfaced animal for a brief period of time (a knob controls the length of this time interval).

The importance of the feedback provided by the Flexi-Formboard has been demonstrated by children with sensory disabilities as well as some with developmental delays, who showed no interest in doing any types of puzzles except for this device, which held their attention for long periods of time. Practicing the skills involved in completing formboards is especially important to children with visual, motor or cognitive disabilities, as it helps improve fine motor coordination as well as develop a variety of spatial concepts.

The Auditory Arcade

The Auditory Arcade is a self-contained computerized educational game. It is a modular system consisting of a metal box whose top surface is formed by interchangeable "Playing Panels," and which houses electronic components, including a 6502 microprocessor chip and speech synthesizer, within. Each Playing Panel presents the user with manipulatable materials of a given theme. For example, the Manipulation Panel has 16 different sets of conventional hardware such as a lock and key, alligator clips, battery snaps, etc.; the Match-Maker Panel has 16 pairs of different textures to be matched; the Moving Experience Panel has 16 plastic discs, each of which is mounted on a spring-loaded switch which can be moved in only one direction.

The user can choose to interact with the Auditory Arcade in any of three basic ways for each Playing Panel: (1) the user simply manipulates any of the materials on the Playing Panel and the speech synthesizer responds by announcing the name of that piece of hardware or the number assigned to that task (the different textures and plastic discs are numbered in sequence left to right and top to bottom - an important order to become familiar with for young people who are either future print readers or future braille readers); (2) the computer initiates the activity by requesting the user to perform a particular task, and the speech synthesizer responds to correctly completed tasks via one of several positively reinforcing statements (e.g. "Nice job," "Good for you!"), and to incorrectly done tasks with the statement "Try a little harder" followed by a repeating of the task to be done; and (3) the computer again initiates the activity by stating which task the user is required to perform, and feedback is presented via the speech synthesizer, but this time the user is asked to perform an ever-increasingly long list of tasks on the Playing Panel.

The modularity of the Auditory Arcade achieved by the interchangeable Playing Panels gives the system potential as an important tool in the classroom or in therapy situations. That is, teachers could request fabrication of a Playing Panel with particular tasks within a given curriculum; therapists and physicians could request fabrication of a Playing Panel requiring particular motor tasks. In either case, since the "supervisor" is built into the system, the user is given much independence to perform the prescribed activities without sacrificing vital feedback.

The Tact Tell System

The Tact Tell System is a sort of Auditory Arcade in which the Playing Panels are replaced by a wide variety of manipulatable educational materials which act as computer peripherals. Each of these is equipped with electronics to monitor status and to interface with a computer which, in turn, is interfaced to a speech synthesizer. This arrangement affords much more flexibility than the Auditory Arcade in terms of design of both hardware and software variations.

Prototypes of the Tact Tell System suggest that some simple, basic educational materials can serve an enormous age range of users. For example, in the Tact Tell Tick Tock the peripheral is a wooden clock face which has been modified to have the hand locations monitored electronically and the information fed into an interfaced "talking" computer. The software designed for the very young child using Tick Tock directs the system simply to announce what time the clock is set for. The older child, in contrast, is requested to set the clock for a specific time, or even to solve simple time problems (e.g. "It is now noon; what time will it be in half an hour?"). Yet the same system can present adults with more sophisticated time problems such as those involving travel through different time zones. Other existing prototypes of the Tact Tell System involve a unit on counting and sorting shapes, and one on solving geography problems with a puzzle map.

CONCLUSION

Toys and games are vital developmental tools for children. Some of today's commercially available products, especially computer games, cannot be used by blind children. Through the innovative wedding of traditional manipulatable educational materials with electronics, computers and speech synthesizers, a new genre of toys and games has evolved. The manipulation requirements and auditory feedback provided by these devices make them usable by both blind and sighted youngsters. The commercial potential of the toys is evidenced by their universal appeal to both children with a variety of disabilities as well as able-bodied youngsters.

ACKNOWLEDGMENTS

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A UNIVERSAL JOB INSTRUMENTATION SYSTEM FOR THE BLIND ("FLEXI-METER")

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INTRODUCTION

The Smith-Kettlewell Flexi-Meter represents an attempt to provide a more flexible approach for instrumenting job modification for the blind. Traditionally, when quantities such as temperature, pressure, voltage, etc. are required to be read as part of a job, a separate instrument with either audio tone, tactile, or talking output has been designed or adapted for each. By contrast, our "Flexi-Meter" approach uses a programmable micro-computer system to adapt to a wide variety of inputs - and provide any of several types of output which are accessible to the blind and deaf-blind user.

SUMMARY OF MARKET SURVEY

A questionnaire about the proposed design was sent to one hundred recipients, taken from the mailing list of those who receive our Annual Reports. Besides the vocational rehabilitation services of all fifty states, other educational centers and training programs were targeted. Thirteen responses were received, and a summary of these follows:

Lost Jobs

All thirteen thought the instrument would serve needs not currently addressed. Two specific job losses were mentioned. One involved servicing diesel engines: some of the test equipment (calibrated flow meters for injector adjustment, for example) was not accessible. The other job was that of a cement mixer: two scales and a water meter were never made accessible, and this job was not given to the blind client. Other respondents mentioned quality control, machining, electrical assembly, assembly-line work, electrical engineering, testing telephone switching, reading conditions on telephone switchboards and dispatching equipment, and chemical work (both in university and industrial settings).

Comments of two respondents were especially significant in the field of expanding vocational opportunities. It was pointed out that where no adaptive equipment exists, jobs are dismissed - or not thought of - by counselors. Many jobs are only considered as options after it is known that someone has equipment that makes them accessible. Conversely, and unfortunately, new jobs are rarely referred to a rehabilitation engineer, so the equipment that would "prove" them does not appear.

An Instrument of Change

A general hope was that a versatile appliance like the Flexi-Meter might become a "forcing function" to promote expansion of jobs if its flexibility matches expectations. Some respondents felt that merely mentioning the Flexi-Meter's existence would help vocational counselors "sell" the client to the employer.

Cost and Availability

An estimated maximum cost of $2500 was considered acceptable to ten respondents out of thirteen, with the remaining three being divided on this issue (with one feeling the cost was too low). The value of the device is dependent on its ready availability; if it takes too long to outfit and program it, job opportunities will be lost in spite of its existence.

CURRENT FLEXI-METER DESIGN

Design Philosophy

Available single-board computers (upon which the earlier refrigeration gauge system design was based) cost a minimum of $250, to which must be added the cost of additional memory, expensive cabling and other hardware, a speech output unit, analog-to-digital converters, and power supplies; this may result in greater than reasonable expense. Similarly, a study of other commercially available computers intended for industrial control applications reveals that these systems are also very expensive, and that no complete unit could be purchased "off the shelf" to fulfill our needs. Consequently, the most feasible and economical approach for the Flexi-Meter appears to be the custom design of our own single-board computer device to incorporate the needed additional components.

Our prototype design is based on the commonly available Zilog Z80 microprocessor, and incorporates only components which can be inexpensively obtained from more than one source. This approach appears to hold the best prospect for minimum cost in eventual production.

Since provisions for customized input circuits and output drivers will be included, and since the first consideration will be adaptability to a wide range of uses, there are practical limits on the instrument's size and weight. While it will be hand carryable, it will never be as small as a single-function display talker, for example. As planned, it will be transportable enough to move from job to job within an industrial setting, and will have convenient connectors for changing one's location in this way.

The unit is expandable, especially for adding of new input and output devices as needs become apparent. The unit has internal space and connections for the addition of as many as eight separate input sensors and several output systems. Software will adapt readily to the sensors and output modes.

As appropriate for some jobs, the instrument can indicate the status of a number of sensors at desired times and conditions (including automatic warnings if needed.) User programmability of various features can be made available.

Given the machine's limited speech vocabulary, it will never serve as a general read-out for a wide range of computers; it is not a computer access system.

Design Features

The device does not have a computer-like keyboard, or any form of complex display. Controls have been limited to a volume control knob and a small keypad which incorporates scale-selection switches. This pad can be used for entering numbers where appropriate.

As a "dedicated computer" consigned to performing specific functions, the Flexi-Meter's operation is kept simple. The accompanying operations manual will be short and straightforward. The fact that the device is based on a computer should not be of any consequence to the operator - as far as he is concerned, the Flexi-Meter is merely an efficient tool. Thus the need to learn complex operating procedures has been eliminated.

Inputs may be taken from a wide variety of industrial sensors and from existing equipment which has electrical output signals available. The Flexi-Meter will accept analog signals as well as digital information in a wide variety of formats including standard serial and parallel interfaces. For example, a single Flexi-Meter could easily be customized to read information from a scale, a micrometer, and a pressure gauge; or it could be the heart of a complete weather station.

Existing software in the Flexi-Meter can process and scale data from these inputs to give the user information in a form which is meaningful to his job. Some "user programmability" is available - for example, setting limits in a measurement range, or setting a relative "zero" around which measurements may be computed.

Output modes can include: Speech, variable tones, Morse code for the deaf, tactile variable low-frequency vibrations for the deaf, and capabilities for driving braille displays or hard-copy printers.

CURRENT STATUS

Initial software development has been completed, and in-house and field trials are under way. When this testing is completed, required design changes or improvements will be incorporated and production engineering will commence.

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NAVIGATION DEVICE FOR THE BLIND

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A research project is underway whose objective is a portable, low cost navigation aid for blind travelers using various modes of transportation. It is directed to orientation, where you are, rather than to spatial sensing which has been the thrust of most devices for the blind to date. The system requires nothing but the portable unit itself. New yet proven technology is proposed to provide continuously updated information of position along a predetermined route. Radar derived doppler and a solid state compass are used to input distance and direction to a microprocessor with a speech synthesis output. This is compared with prerecorded distance and direction information on a cassette to aid the traveler to repeat the prescribed course.

A portable radar device is being implemented and tested to verify that accurate distance measurement can be achieved from inside a moving vehicle such as a city bus as well as for a walking person. This technology will be combined with experience gained with blind subjects using a simulation of the proposed device to show that such information is adequate for the user to navigate a prescribed route.

MAPPING METHODS

There are two ways that people consider geography. The first way, a two dimensional representation, corresponds to a printed map. To get from one place to another you have to find both starting and ending points on the map and study the paths between the two points. This works well in a city with a regular grid of streets. It is complicated for a blind traveler in that he has to know the names and the order of all the streets if they are not simply numbers. This method is the only one that can work for any arbitrary destination.

Another way we can consider geography will be termed a "one dimensional map." This means logging a sequence of landmarks and directions to get from one place to another. "Turn right out of your apartment, go three blocks and turn left on Main Street, then go one block and turn right at the Standard Station ...." Our actual first-hand experiences traveling are all one dimensional. One dimensional maps are easy to follow but they only go on routes you know or that have been described for you. When you look at a map to get someplace you mentally translate the two dimensional map into a one dimensional sequence of instructions. This proposal will initially be for a one dimensional mapping device based on known routes that someone has recorded. It is the investigators' belief that this method is practicable within a moderate development program. If techniques are discovered that make 2D mapping attractive, future directions will follow that route.

NAVIGATOR PRELIMINARY DESCRIPTION

The Navigator incorporates a tape recorder (Walkman type), a K band doppler radar head (the type used in burglar alarms), analog circuitry to process the distance similar to that used in the Nike Monitor, an electronic compass, a microcomputer with speech synthesis capabilities, several control buttons and earphone or speaker output. It must be a portable unit wearable around the waist and should be as unobtrusive as possible.

To make a cassette the first time, a sighted person walks the new route with the blind traveler or for him. This step might be eventually replaceable with a central database call or eventually with a portable map. The first time on a route a blank tape is put in the cassette. At each significant point along the route such as a street to cross, a corner to turn at, a bus stop marking a bus entry point, the place to get off the bus, or a doorway, a button is pushed and a spoken description of the "landmark" (such as "Main Street") is recorded. The Navigator automatically logs the distance from the last landmark and the compass bearing as digital information on the other track of the tape.

Thereafter, each time the blind user wants to get to a specific place that had been previously taped (i.e., the library) he selects the cassette for that route, puts it in his Navigator, presses the start button and starts to walk. Ten feet (1000 feet if it is a bus leg of the trip) before each landmark the machine beeps. The user can listen to the recorded description or skip it. Pressing a button at the precise location of the landmark keeps errors from building up. Buttons also provide for listening to the next description (where we're going) or to the previous one (where we were). At any point between landmarks a "progress" button activates a speech synthesized report of distance from the last landmark and distance remaining to the next one. The system should provide for reversing the course for the return trip by playing the descriptions in reverse order.

A built-in compass automatically records bearings between each landmark. A significant deviation from the correct direction when traveling activates a warning. A button is also provided to read the compass using the speech synthesizer.

Mixing the audio frequency electronic doppler signal from the radar unit with the speech synthesizer audio can provide some audio indication of objects ahead and of approaching people in the same fashion as in existing spatial sensing devices. This will be provided as a switch selectable option for those who find such aids valuable. It does not add any cost to the device beyond that of the option switch.

We believe that a device such as we are developing can have genuine utility to blind travelers attempting to navigate to both familiar and unfamiliar destinations. Its use on public transportation should give it value even to experienced blind travelers.

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THE GENERIC VOICE MODULE: THE DESIGN AND APPLICATION OF AN AID FOR BLIND AND VISUALLY IMPAIRED PEOPLE

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ABSTRACT

The development and needs for a generic voice module are presented. Various types of interfaces to commercial products for blind and visually impaired people are discussed with specific discussion of a talking glucose analyzer and a talking analytical scale.

INTRODUCTION

The National Technology Center of the American Foundation for the Blind has developed a generic voice module (GVM) to allow easy and rapid addition of speech to commercially available devices containing output ports.

BACKGROUND

The growing need for voice output devices

Synthetic speech is an effective method of providing accessibility to consumer products for blind and visually impaired people. Products available with synthetic speech include calculators, watches, machine shop tools, medical devices, and cash registers. The increasing number of devices on the market with EIA or RS-232c type interfaces facilitate this type of output.

Previous development cycles

The development of voice output devices for blind and visually impaired people has been accomplished through a number of processes. Most common among these has been to simply take a device with voice output that was developed for the consumer market and offer it as an adaptive aid. Among these devices were talking calculators and watches. When speech synthesis was relatively new this approach worked well because many of these devices were being developed by manufacturers eager to cash in on a lucrative new market. However, in recent years, the market for these devices has diminished thus making this relatively low-cost approach less common.

Another approach that has been implemented when an existing talking consumer product is not available, is to adapt an existing non-talking device for speech output. This method has the advantage of allowing the engineer to modify virtually any available consumer electronic device with synthetic speech output.

However, the development time for this type of device can be long. Often this type of adaptation requires extensive internal modification of the device as well as the development of a voice output module. In some cases up to one year can pass before a product is released in production form. These factors result in two problems for the consumer: only a limited number of devices can be produced and a high cost results from the lengthy development time.

The advantages of the GVM approach

The proliferation of the personal computer in all areas of life has introduced a new method of designing adaptive aids. It is increasingly common to find various types of ports on devices so that a computer or data-logging system may be attached to read the data from the device. In the same way a GVM may be interfaced to the port of this type of device to annunciate the data from the device. Once the GVM is designed with various interface port capabilities, further hardware modification is not neccessary either to the consumer product in question or to the voice module.

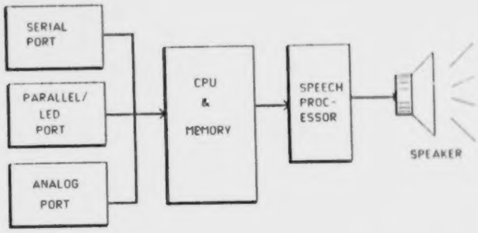
The modifications necessary include: software for recognition of the device's data format, a matching connector and the appropriate vocabulary.

The result is that low volume semi-custom speech output devices can be produced within a short time frame. Since the hardware is the same for all these devices the generic voice module can be built in large quantity thus giving the mass production benefit of low cost.

RESULTS

Features of the GVM

The design of the GVM (see Figure 1), which is based on the Intel 8031 microcontroller, allows it to be connected to various devices through several different interfaces. The 8031 has built-in parallel and RS-232c serial interface capabilities which makes it an ideal candidate for the design.



GENERIC VOICE MODULE BLOCK DIAGRAM
FIGURE 1

The personal computer revolution has introduced a market for a wide range of data-aquisition devices that have built-in RS-232c serial ports. The GVM enables devices to be easily accessed by voice output. For those devices that have a built-in analog output, it is possible to add an analog-to-digital hardware module to the GVM.

The GVM uses speech synthesis to convert the data from the device interface into high quality speech. The Signetics MEA8000 speech synthesizer used in the GVM is a limited vocabulary formant synthesizer that takes digital codes and translates them into the pitch, amplitude, and filter control information needed to recreate the original speech. These digital codes are created in-house using a personal computer, the Phillips/Signetics speech editing system, and an high-fidelity cassette tape deck. The required vocabulary, which is recorded by a professional announcer at AFB's recording studio, is digitized using the speech editing system, and the resulting speech codes are stored on an on-board EPROM. This allows each device to have a custom, high quality voice output. In a typical 8K byte eprom approximately 36 words can be stored.

PRACTICAL APPLICATIONS

Recently, the National Technology Center has adapted two commercial devices. The Ohaus corporation manufactures high quality precision scales for laboratories and industrial uses. These scales provide output through a DB-9 type connector. The output available includes all data that appears on the digital display. The GVM has been designed to capture this data and annunciate it with synthetic speech. This scale together with the GVM can be used in a variety of laboratory and industrial applications with complete access by blind and visually impaired users.

Recently, Lifescan, a Johnson & Johnson company, introduced a low-cost blood glucose analyzer for use by people with diabetes. The Lifescan One Touch® system provides output through a bi-directional serial port to a printer for data logging. The GVM was interfaced to this port to allow blind and visually impaired diabetics access to this glucose analyzer. Diabetes is the leading cause of new blindness in the United States and careful monitoring of blood sugar levels is crucial. The GVM allows low-cost access to a device that previously was unavailable to visually impaired consumers. In addition Lifescan designed the One-Touch® system with the needs of visually impaired people in mind by incorporating a large LCD display and simple one button operation.

LIMITATIONS

The GVM is not a text-to-speech device (i.e. Dectalk® or Echo®). The vocabulary is limited to a pre-selected list that is stored in EPROMs. The firmware must be changed for each device to be accessed. Most commercial devices do not adhere to the same RS-232c standard. Many types of connectors, transmission rates, and protocols exist. The hardware can remain constant but vocabulary selection and software for data capture are tailored to each device.

CONCLUSION

The quantity production of a generic voice module and the increasing use of output ports on commercial devices provides for an inexpensive solution for accessibility by blind and visually impaired people. Given some limitations, this approach offers a flexible, high quality speech output to equipment that previously was inaccessible without expensive modifications or custom designed equipment.

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TACTILE AIDS TO LIPREADING: CURRENT STATUS AND FUTURE PROSPECTS

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INTRODUCTION

Since Gault (1924) (1), there have been attempts to develop devices to provide speech to the skin of profoundly deaf individuals. The skin stimulation has generally been in the form of mechanical vibration or electrical pulses delivered by electrodes placed on the skin surface. Although in the past work was fueled to a greater extent by optimism than by results, today, wearable tactile devices are available commercially and research is ongoing at several laboratories in the United States and elsewhere. The devices are typically either multichannel, providing speech frequency information in terms of position of stimulation, or single-channel, providing rhythmic or prosodic information. This paper is concerned with interpretation of past results and the program for future research and development.

SUMMARY OF RESULTS

Current tactile devices may serve best as supplements to lipreading rather than as stand-alone prostheses. Benefits observed in recent studies were examined in terms of the performance of the most successfully aided subject(s). The subjects' task was connected discourse tracking (CDT)(2): an experimenter reads from a text, and the subject is required to repeat it back verbatim. Words-per-minute correctly repeated is the obtained measure. Unaided lipreading tracking rate (LR) vs. relative improvement, was examined (3). Table 1 summarizes results and information about the subjects' hearing, duration of training, and device. At the rate of 70 WPM, the receiver must ask for a repetition of about one third of the speech (3). 110 WPM is a result for normal-hearing auditory performance of the task (4). All aided subjects approached or achieved the 70 WPM goal, but none surpassed it. Most important to note, is the essentially similar performance achieved by all subjects, regardless of experience or hearing (see Table 1).

EFFECTS OF LEARNING VS. TACTILE DEVICE CONFIGURATION

What factors may have contributed to the overall level and uniformity in these results? First, Table 1 does not reveal that, with only two possible exceptions, none of the subjects appear to have reached asymptotic performance at the conclusion of testing. But it would have been extremely unexpected to discover that they had, since learning to identify complex stimuli is a most difficult task (5). Use of tactile devices to perceive speech may require long periods of experience. Therefore, some experiments must be conducted for as long as required to obtain asymptotic performance, before estimates can be made of the upper bounds on performance. Second, it is possible that the uniformity of aided CDT rates could, ceteris paribus, be evidence of an absolute limitation on the benefit that can be achieved with current devices. To understand possible sources of limitation imposed by the devices themselves, consideration of the Tadoma method of speech reception is helpful.

By Tadoma a small number of blind and deaf people receive speech by placing their hand on the face and throat of the talker. Tadoma users have achieved adult levels of written and spoken language, although deafness was prelingual (6). Conversations with them can proceed at slow to moderate rates (7). Let us suppose that the success of Tadoma users is due not exclusively to the intense long-term training required but to the complex multidimensional stimulation they receive. For example, place of articulation of phonetic segments may be obtained from dynamic geometric properties of the talking face and manner from face geometry and air flow source and quality of motion (7). Up to eight different kinds of nerve fibers participate in transducing this information, whereas three or fewer kinds of fibers transduce the vibratory stimulation (8). Better results may be achieved with devices that are more closely modeled on Tadoma.

SUGGESTIONS FOR FUTURE RESEARCH

1. Longitudinal studies of device efficacy should be conducted with both children and adults. 2. Research should be directed towards new transducers. 3. Understanding of tactile and visual-tactile perception and learning must be achieved.

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Table 1. Length of training, hearing status, and device tested with subjects who provided best performances in the connected discourse tracking procedure.

Author(s)	Subject(s)	Length of Training^{b}	Type of Device	LR	LRA	LRA/ LR
Cholewiak & Sherrick (1985)(9)	Profoundly Deaf Male	13 years	2-chan	44	57	1.3
Brooks et al. (1986)(9)	Normal Hearing Female	221 hours	16-chan	15	50	3.3
Potts & Weisenberger (1987)(10)	Normal Hearing	>13 hours	16-chan	26	65	2.5
Grant et al. (1986)(11)	Subj. 1, Normal Hearing;	>10 hours	10-chan^{e}	43	56	1.3
Grant et al. (11)	Subj. 2, Profound Deaf	>10 hours	10-chan^{e}	56	67	1.2
Sparks et al. (1979) (4)	Normal Hearing	20 hours	36-chan^{e}	50	50	1.0
Plant et al. (1984) (12)	Profoundly Deaf Female	3 years	1-chan	43	56	1.3
De Filippo (1984) (13)	Normal Hearing	>50 hours	4-chan^{t}	53	70	1.3

Notes. ^{b} Estimated practice time with some type of tactile device for speech reception. ^{c} Mechanical vibration unless otherwise noted (^{e} = electrotactile; ^{t} = both). LR = Lipreading unaided. LRA = Lipreading Aided.

THE DEVELOPMENT OF ARTIFICIAL HEARING THROUGH THE SKIN

Rebecca E. Eilers, D. K. Oller, Michael P. Lynch

THE DEVELOPMENT OF ARTIFICIAL HEARING THROUGH THE SKIN

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Michael P. Lynch, University of Miami

Tactual vocoders are devices that present sound to the skin as vibratory or electrical stimulation. The acoustic signal is divided into channels (commonly 16 to 32) which drive stimulators representing specific acoustic frequency bands. The stimulators are worn in a linear array on a chosen body site. By displaying frequency information as a function of stimulator position on the skin, vocoders overcome the basic drawback of the tactile system, its lack of frequency resolution beyond about 200 Hz. Acoustic intensity may be coded as vibration or pulsation frequency within the skin's sensitive range.

Recent research in both psychophysical laboratories and classrooms for the hearing impaired have made it clear that the vocoder approach to sensory substitution is a viable one. Basic psychophysical research has focused on just noticeable differences in the skin's ability to detect electrical frequency (3). This information was used to design the intensity coding scheme for a computer-driven 32-channel electrocutaneous laboratory vocoder (18). A comparison of auditorily and tactually presented computer-synthesized speech syllables showed convincing similarities in perception between the two modalities (6). Additional psychophysical research demonstrated that for some speech syllables, the similarity was not dependent on the configuration of the vocoder filter banks (linear, logarithmic or average of linear and logarithmic). Rather, speech identification and discrimination was based on general pattern perception similarities in the two modalities. Filter configuration adjustments may be critical for special functions such as detection of fundamental frequency.

Promising results have not been limited to laboratory computer-driven vocoders. A variety of tactual vocoders have been shown to transmit a number of speech cues that are hard to lipread and difficult to transmit through hearing aids. In particular, high frequency sounds (fricatives, affricates, stop bursts) and high (friction) and low (voicing and nasality) frequency features are well transmitted through tactual vocoders but are not easily available through lipreading (19, 21, 17, 7).

Vocoders also aid the perception of words and conversational speech. A number of recent studies with both deaf and hearing subjects have shown that significant speech recognition can be obtained after 40 or more hours of training with tactual vocoders. The type and amount of training appears to be significant.

The most successful training methods involve structured unimodal tactual practice in which vocabulary recognition is emphasized first. Words selected from a short list are presented one at a time, and the subject is required to determine which word was spoken. Feedback is provided on each trial. As the subject demonstrates proficiency by maintaining a high percent of correct responses, the list is systematically increased in size. Both deaf and artificially deafened subjects who have participated in extended training (up to 200 hrs) have demonstrated vocabulary acquisition rates of 1-3 words per hour. More importantly, no subject's learning curve has reached asymptote, but, rather, curves tend to be steady or to accelerate over time (9, 1, 15, 23). These data indicate that subjects are organizing vocabulary into functional subunits (phonemes or syllables) which may be recognized and combined in novel patterns similar to the manner in which new vocabulary is learned through the auditory system.

Recent data from profoundly deaf children and adults (12, 13) indicate the efficacy of unimodal training as well as the potential for integrating the tactual signal with that from aided audition. Both adults and children showed improved performance when aided audition and taction were combined compared to the use of either modality alone. This improvement in performance extended to novel words used in the generalization phase of the studies. The demonstration that information available through different sensory modalities is complementary is a necessary feature of a successful sensory prosthesis.

Following vocabulary acquisition, subjects may be taught to recognize sentence-length material composed of words from the tactual list. The ability of subjects to learn to recognize a specified closed set of words and sentences composed over those words is intriguing but insufficient to show the full potential of tactual devices for the deaf. Practical prostheses must aid in the tracking of connected discourse in conversational settings. Variants of DeFilippo and Scott's (4) tracking procedure are often employed for simulating conversational settings. Practiced subjects are presented with unfamiliar passages which they must repeat phrase-by-phrase. Mistakes require retracing, and consequently reduce the tracking rate. A comparison of tracking rates with lipreading alone or lipreading plus the tactile signal provides an indication of the efficacy of the tactual vocoder as a practical supplement to lipreading. Research with several different tactile devices has shown that tracking rates increase significantly when the tactile and visual signals are combined (2, 22, 11, 14). A further enhancement for a deaf user was obtained by combining aided hearing with vision and taction (14).

Since these results have been found in a number of laboratories with both deaf and hearing subjects, there is no longer basis for doubt that tactual aids can serve as speech transmission systems. These results have inspired the development and growth of training programs for deaf children using tactual vocoders as a primary educational tool (see 16). Enthusiasm for such approaches is growing rapidly as results mount, indicating excellent outcomes in speech perception, speech production and academic skills for children who use tactual devices in intensive regular training.

Future educational applications will require engineering of a new generation of tactual vocoders. Currently, the 16-channel Tacticon unit (20), which is battery powered and miniaturized, is the choice for classroom use. However, test results suggest that the Tacticon is less effective in assisting users in conversational speech than vibratory vocoders (see 1). Poorer performance of the Tacticon seems to be associated with the nature of the stimulators. The greater effective dynamic range of the vibrators used in the Brooks and Frost device appears to produce a clearer signal. The disadvantage of these stimulators, however, is that they are power hungry and bulky, and consequently make miniaturization unlikely. Several investigators are attempting to implement a miniature vibrotactile vocoder using smaller stimulators developed by Franklin (10). It is clear that major improvements in tactile aids are possible if stimulators with good dynamic range can be implemented in a miniature device.

Another major issue in the engineering of better vocoders is the implementation of digital approaches to field devices. The Tacticon is an analog system and lacks much of the flexibility that would be desirable in a prosthesis. Digitally based signal processing for tactual vocoders has been developed (8, 18). Such work has two key benefits: 1) it provides the basis for efficient experimentation on different vocoder configurations (see 6) and 2) it facilitates miniaturization and upward compatibility of devices.

The development of effective practical tactual vocoders seems destined to play a key role in the education of deaf children of the next generation. This conclusion is based upon the growing body of evidence of the utility of presently available devices and upon the fact that other alternatives for the prelingually deaf (especially cochlear implantation) have yielded disappointing results. As tactile devices continue to be improved through engineering and perception research, they will play a larger role as hearing prostheses.

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OPTIMIZATION OF SINGLE ELECTRODE TACTILE CODES

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ABSTRACT

The goal of this study is to determine the optimal single-electrode tactile code. This code may then be applied to sensory aids for the blind or deaf and to sensory feedback systems in artificial limbs and functional electrically stimulated hands. The search for an "optimal" single channel electrocutaneous code involved the comparison of various encoding schemes, frequency ranges, and pulse width compensation. The psychophysical experiment being conducted and the data collected to date are presented in this paper.

INTRODUCTION

Stimulation of the skin surface using mild, well-controlled electrical pulses (electrocutaneous stimulation) has been shown to be useful for providing sensory feedback in artificial limbs, feedback of command signals for FNS based upper limb prostheses, tactile vocoders for deaf persons, and mobility aids for the blind. Research has also shown that the manner by which an informational signal is converted (or encoded) into a stimulus pattern has significant impact on the clarity and accuracy with which that signal is perceived and thus a significant impact on the ultimate efficacy of the sensory aid which incorporates that code.

One method by which various coding schemes may be quantitatively and objectively compared is electrocutaneous tracking, wherein a subject is presented various patterns of electrocutaneous stimulation based on the code being tested. The subject attempts to accurately and quickly interpret and respond to these tactile sensations by moving a joystick in a pursuit tracking task. The underlying hypothesis in this approach is that superior tracking performances by a number of test subjects on a particular code would indicate a superior code.

DESCRIPTION OF THE EXPERIMENTAL APPARATUS

In order to expedite the testing of various electrocutaneous codes (the transfer function by which an informational signal is mapped into stimulation parameters), software and hardware implementation of the electrocutaneous tracking task has been completed on an Apple IIe. The experimental apparatus uses a 6522 parallel I/O card, specially designed interface unit, and some user friendly software to do the following:

- generate a random target signal (out of 32 possibilities) that changes every 5 seconds.
- display the target signal on a scope.
- convert the target signal (via a pulse rate modulation transfer function) into a stimulus frequency 2 to 50 Hz or 2 to 100 Hz.
- apply a stimulus (via a concentric bipolar surface electrode) to the ventral forearm having either a fixed pulse width of 200 us or a variable pulse width for a more even level of stimulation intensity (pulse width compensation).
- sample and record at 20 Hz the subject's joystick responses.
- off-line analyze the tracking data by performing RMS error calculations and by determining the amount of time shift (or response latency) between the response data and target data that produces the minimum tracking error.
- permit off-line inspection and printout of the raw tracking data.

COMPARISON OF CODES

An information signal can be encoded into tactile patterns by varying parameters such as the pulse width, pulse frequency, and amplitude. The six codes in this study examined the following stimulation options: total frequency range, shape of the transfer function, and the use of a pulse width compensation formula (derived from previous research) for maintaining a constant intensity level of stimulation despite frequency changes in the stimulus waveform.

The hybrid codes (B, D and F) increase linearly in frequency from 2 to about 10 Hz (target position 4) and then increase exponentially from there to their maximum pulse rate of 50 or 100 Hz for target position 10. The three exponential codes (A, C and E) use a fixed exponential function to map the informational signal (i.e., the target position) into pulse frequencies 2 to 50 Hz or 2 to 100 Hz.

ELECTROCUTANEOUS TRACKING

The electrocutaneous tracking task required a subject to estimate the target's horizontal screen position based solely on the frequency of the tactile sensations felt on his ventral forearm. The subject would indicate his estimate of the target location by placing his response dot in that screen location. The subject's tracking performance, in terms of the mean error, was monitored in real-time by proportionately converting the absolute tracking errors into pulse frequencies and summing them for an entire tracking run. The subject's tracking performance was also digitally stored for later detailed analyses in terms of the average RMS tracking error and latency of the subject's responses.

EXPERIMENTAL DESIGN

The study used a repeated measures, balanced block design involving 30 subjects, each of whom is randomly assigned an ordered pair of two different test codes. Each code would be tested by 10 different subjects, five times during the first of two test sessions and five times during the second test session in order. To counterbalance possible learning effects, each sequence of two tests performed by a subject would also be performed by another subject in exactly the reverse order.

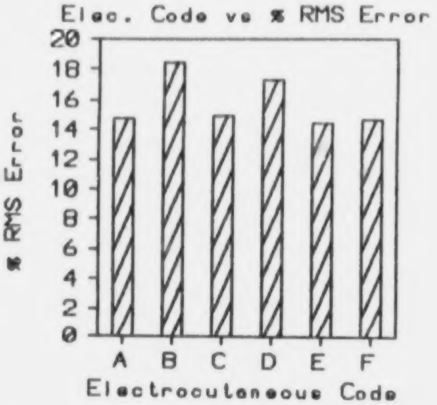
EXPERIMENTAL PROTOCOL

Two test sessions of 1-2 hours each were needed to collect the necessary tracking performance data. The protocol used for every test session was as follows:

- explain purpose of research to subject.
- obtain three visual tracking tasks.
- explain the purpose of electrocutaneous tracking tasks.
- attach a concentric bipolar electrode to subject's non-dominant forearm and adjust the stimulus current until the tactile sensation was distinct and comfortable.
- teach the subject the various tactile patterns associated with various target positions (training).
- carry out nine electrocutaneous tracking runs of 90 seconds each.
- provide brief reviews between tracking runs as necessary to improve or maintain training and mental alertness.
- have the subject complete a questionnaire regarding the difficulty and clarity of the tracking task and the degree of mental effort necessary.

RESULTS

Approximately 40% of the total experimental RMS error data has been collected to date. The bar graph below summarizes the overall average RMS error for each of the six codes tested. Although the incompleteness of the data collected to date does not permit a full statistical analysis, the bar graph seems to indicate that the exponential codes (A, C, and E) and the use of pulse width compensation yield better (or more interpretable) tactile codes. They produced lower RMS tracking errors by allowing subjects to more accurately and rapidly track an informational signal. The hybrid codes which do not incorporate pulse width compensation (Codes B and C) appear to yield larger RMS tracking errors. More definitive conclusions, however, must await the completion of the planned study and the detailed statistical analyses of all the tracking data.



EVALUATIONS OF TACTILE AIDS FOR THE HEARING-IMPAIRED

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INTRODUCTION

In recent years, a variety of tactile devices designed to present speech information to hearing-impaired persons have become commercially available. Technological advances have reduced the size and power requirements of these devices such that they can now be worn even by young children. Presently on the market are single-channel, two-channel, and multichannel devices, providing vibrotactile or electrotactile stimulation to diverse body locations, and utilizing a number of different signal processing strategies.

Work in our laboratory attempts to determine the kinds of information that can be obtained from single-channel, two-channel, and multichannel tactile aids, and thereby suggest situations in which each type of device might be useful to a hearing-impaired person. Over the past several years a number of different tactile aids have been evaluated in our laboratory with various types of acoustic input. We have assembled a series of tasks which permits evaluation of the ability of tactile devices to provide information about acoustic stimuli at various levels of analysis, for example, phoneme, syllable, word, and sentence levels. At the same time, this series is used as a training paradigm for subjects, with tasks organized in a hierarchy from relatively simple to relatively complex.

Results with simple single-channel tactile aids have shown benefits in the detection of sound and in the identification of sounds that differ in amplitude envelope characteristics, but the data are equivocal as to the benefits of such devices to connected speech perception. Attempts to provide additional spectral information by coding frequency as location on the skin surface along an array of tactile transducers have been more successful, and have resulted in better speech perception performance than is found with single-channel devices (1,2).

In our laboratory, both single-channel and multichannel tactile aids have been tested using the series of tasks described above, and from the data collected, some generalizations can be drawn as to the amount and quality of information about acoustic signals that can be conveyed by each type of device.

DEVICES TESTED

The tactile devices that have been tested in our laboratory include the Tactaid I, II, and V (Audiological Engineering), the Minivib3 (AB Special Instrument), the Minifonator (Siemens Hearing Instruments), the TC-1600 (Tacticon), and the Queen's University tactile vocoder.

PROCEDURES

Tests employed in these evaluations include minimal pairs phoneme discrimination, phoneme identification in closed sets, word learning, phrase and sentence identification, and connected discourse tracking. These tasks are used for training as well as evaluation, such that a number of test sessions is obtained with each task, and are arranged from simple to complex to facilitate learning with a tactile aid. Subjects are trained in initial tasks under tactile aid alone conditions, and are later trained to integrate tactile information with visual information from lipreading.

RESULTS AND DISCUSSION

Typical performance in minimal pairs phoneme recognition for four subjects tested with single-channel and multichannel tactile aids, under tactile aid alone conditions, is better for multichannel devices than single-channel devices. Manner features of speech are conveyed most effectively by these devices, whereas place information is conveyed rather poorly. Given that place information can often be obtained by lipreading, and that manner information typically cannot, a tactile device that transmitted manner information might be combined with lipreading to provide improved benefits.

The results of such a combination are shown in Figure 1, in which performance under lipreading alone, lipreading plus single-channel aid, and lipreading plus multichannel aid conditions are displayed. Performance under the lipreading plus tactile aid conditions is superior to lipreading alone, and again multichannel devices provide more improvement than do single-channel aids.

However, performance of tactile devices with single-item stimuli in closed sets is not a good predictor of the usefulness of a tactile aid in comprehending connected speech. Accordingly, connected discourse tracking, in which subjects repeat verbatim portions of text read to them, was used to evaluate the performance of tactile aids with connected speech. The variable measured in this task is the number of words per minute (wpm) that are successfully transmitted from talker to listener, with normal rates in the vicinity of 100 wpm. To the degree that rates under lipreading plus tactile aid conditions are higher than under lipreading alone conditions, a tactile aid can be shown to provide benefit in comprehending connected speech.

Figure 2 shows data for a typical subject in the tracking task, across test days, under lipreading alone, lipreading plus single-channel aid, and lipreading plus multichannel aid conditions. While performance with the single-channel aid provides an average improvement of about 5 wpm over lipreading alone, a result consistent with other findings in the literature, a much greater improvement is found with the multichannel tactile aid.

In other experiments in our laboratory, tracking rates in excess of 70 wpm with lipreading plus multichannel tactile aids have been obtained. Rates this high begin to approximate "normal" conversational rates, and suggest that a multichannel tactile aid might be of practical benefit in connected speech comprehension. Although substantial training is necessary to achieve such rates, these results are encouraging for the further development of wearable multichannel tactile aids.

To summarize, while some benefits are provided by single-channel tactile aids, the promising results obtained with multichannel devices in laboratory settings suggest that further improvements in the development of multichannel tactile aids, particularly in providing wearable versions of such devices, would be of substantial benefit for hearing-impaired persons who cannot benefit from conventional amplification.

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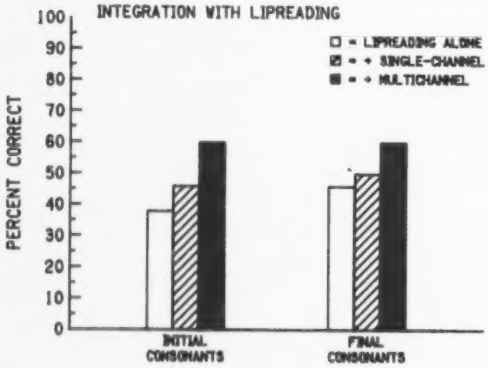

Figure 1. Percent correct phoneme identification in the integration with lipreading task, averaged across subjects, under lipreading alone, lipreading + single-channel aid, and lipreading + multichannel aid conditions.

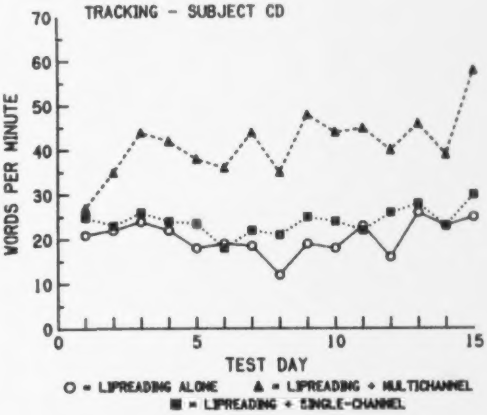

Figure 2. Connected discourse tracking rates for subject CD across test days, under lipreading alone, lipreading + single-channel aid, and lipreading + multichannel aid conditions.

SINGLE AND MULTICHANNEL TACTILE DISPLAYS OF F0 AS AIDS TO LIPREADING: SPEECH PATTERN CONTRAST PERCEPTION

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ABSTRACT

Perception of selected speech pattern contrasts was measured in six normal subjects by lipreading, by tactile presentation of fundamental frequency (F0), and by the two in combination. Two tactile codes were used: 1) temporal, as frequency in a single channel display; and 2) spatial, using a multichannel display. Both displays enhanced perception of voicing and stress contrasts. The multichannel display was more effective than the single channel display in enhancing perception of intonation.

INTRODUCTION

Lipreading by normal subjects is enhanced dramatically by the addition of auditorily-presented fundamental frequency (F0) <1,2>. Similar benefits might be expected for the totally deaf by the tactile transmission of F0. Devices that code F0 for tactile presentation have been built and tested. They do, indeed, enhance lipreading, but their performance falls short of that obtained with auditory presentation of F0 to normal subjects <3,4>. Possible reasons for the discrepancy include insufficient training, errors of pitch extraction, inappropriate coding, and inherent unsuitability of the tactile sense. The present study was concerned with coding. The purpose was to measure and compare the effectiveness of a single channel, temporal, code and a multichannel, spatial, code. Both coding schemes provide essentially equivalent frequency resolution <5>. In the present study, they were to be compared in terms of their ability to convey information about speech.

SUBJECTS

Six normally hearing adults served as subjects in this experiment.

TACTILE CODING

The tactile stimulus consisted of constant amplitude square waves delivered by miniature solenoid actuators. The temporal display used a single solenoid driven at F0/2, the output being applied to the tip of the left index finger. The spatial display used an array of 16 solenoids with 1cm spacing. The driving frequency was again F0/2 but the locus of vibration changed with frequency, lateral displacement being proportional to the logarithm of the driving frequency. The transformation was such that a frequency change of 1/6 octave produced a 1 channel change in place of stimulation. The output stimulus was applied to the medial surface of the left forearm.

TEST MATERIAL

Four subtests of the Speech Pattern Contrast test <6> were used:

1. Roving Stress: location of stress in a three-word phrase
2. Pitch Rise/Fall: rising versus falling intonation contour
3. Initial Consonant Voicing
4. Final Consonant Voicing

A single subtest consisted of 12 trials, each involving a different context for the contrast under test. The tests were presented from video recordings, the F0 contours being derived from an audio track containing the output of a Synchrovoice electroglottograph.

PROCEDURE

Each subject was tested in 22 sessions, each lasting 1/2 hour. There were five test conditions: lipreading alone; single channel tactile alone: multichannel tactile alone; lipreading plus single channel; and lipreading plus multichannel. For each subtest, 6 scores were obtained by lipreading alone, and 4 scores under each of the other conditions. Stimulus presentation and scoring were accomplished via a computer-controlled, video-interactive system <7>. A combination of ear plugs and white noise masking under circumaural headphones was used to prevent subjects hearing the acoustic outputs of the tactile displays.

RESULTS

Figure 1. shows the mean scores obtained under the three single-modality conditions. The light shaded area shows the upper 99% confidence limits for mean scores expected on the basis of guessing alone. All means were at or above these levels, indicating at least partial access to these 4 contrasts by one or more subjects. Final Consonant Voicing was perceived well via all modalities. Initial Consonant Voicing was perceived at very close to chance levels via all modalities. For only one contrast was there a significant modality effect. Pitch Rise/Fall was perceived better via the multi-channel display then via either the single channel display or lipreading alone.

Figure 2 shows the mean scores for speechreading alone and for the two tactually supplemented conditions. Tactile supplementation provided a significant increase in score for all contrasts. For Initial Consonant Voicing, the increase was quite marked. Only in the case of Pitch Rise/Fall was there a difference between the two tactile displays. The multichannel display enhanced lipreading. The single channel display did not.

DISCUSSION

These data are in keeping with the hypothesis that much of the benefit to be obtained from a tactile display may be found in the simple cuing of voice onset and voice duration. The spatial display, however, also appears to be capable of conveying information about F0 changes over time.

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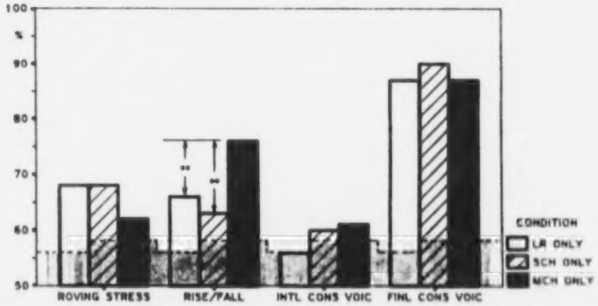

Figure 1: Mean scores of 6 subjects on 4 subtests of SPAC under 3 conditions. Asterisks show significant differences (p<.01).

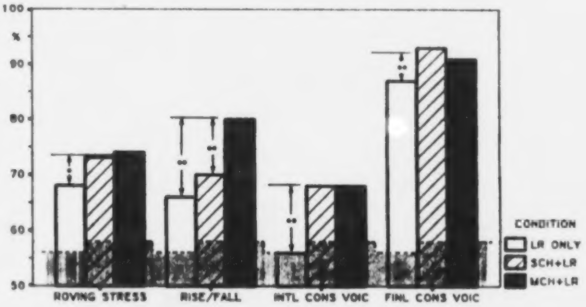

Figure 2: Mean scores of 6 subjects on 4 subtests of SPAC via lipreading with and without tactile F0. Asterisks show significant difference (single, p<.05; double, p<.01).

TOWARD EMERGENCY VEHICLE DETECTION: SYSTEMIC CONSIDERATIONS

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INTRODUCTION

From time to time, attempts have been made to develop a device that would alert hearing impaired drivers to a variety of emergency vehicle sirens (including air horns, warblers, etc.) At present, there is no device that fulfills that function satisfactorily. This paper reviews the need for a device to detect the approach of an emergency vehicle, lists the required attributes of an alerting system, discusses some previous attempts to develop such a device, and suggests alternative approaches for the basic components of the system.

PROBLEM AND NEED

In recent focus group discussions on needs for technical devices [1], hearing impaired people repeatedly expressed the desire to be alerted to approaching emergency vehicles (e.g., fire, police, and emergency medical service vehicles). Although some hearing impaired people do not view this as a problem, many do feel vulnerable because they cannot hear the vehicle's siren.

In fact, vulnerability is not unique to hearing impaired people. Most drivers are functionally hearing impaired when driving with their windows rolled up, air conditioner on, and/or radio playing. Drivers of large trucks may find that the noise from the engine masks most sounds. Emergency vehicle drivers sometimes find that their own sirens mask the sirens of other responding emergency vehicles.

Sirens are usually supplemented by flashing lights, but lights cannot always be seen, especially where line-of-sight is blocked by tall buildings, road signs, or tall vehicles.

The true scope of the hazard has not been measured, but emergency service officials do recognize the problem. In an attempt to penetrate the isolated acoustic environment of automobile drivers, many emergency services now employ air horns and other devices which produce very loud, low-frequency sounds. When large numbers of drivers cannot hear the approaching sirens, at least the following hazards result:

Accidents involving emergency vehicles. The National Highway Safety Administration (NHSA) estimates that in 1986 between 16,000 and 31,400 emergency vehicles were involved in accidents, resulting in 135 recorded deaths [2]. However, data on the specific causes of these accidents are not available.

Increased response time by emergency vehicles. Drivers who do not pull aside can impede the progress of an ambulance, fire engine, or police car. Any delay of responding emergency vehicles can have tragic consequences for those in need of emergency services.

Outrunning the signal. With some of the newer electronic sirens, emergency vehicles traveling at high speed sometimes "outrun the signal." This happens when the vehicle travels fast enough to produce a significant droppler effect which alters the audible warning given to drivers in its path.

RECENT ATTEMPTS AT DEVELOPMENT

A sound-detection device currently on the market is advertised as detecting sirens, among other traffic noises. Informal tests of the device resulted in the conclusion that it is not selective in its sound detection, so that even small road bumps give more powerful signals than sirens. In the past, other devices purported to detect sirens have made brief entries on the market but have quickly disappeared.

In Japan, where deaf persons are denied drivers' licenses, Miyazaki and Ishida [3] designed a traffic alarm monitor based on acoustic monitoring. The device responded to many sounds, not just sirens. The essential operating principle of the device was that siren sounds have sharp line spectra in the real frequency domain, whereas ambient traffic noise is wide-band random noise. Although the authors indicated satisfaction with the performance of the device, we conclude that the number of false negatives and false positive warnings would be unacceptable to American drivers. For example, in a road-test in downtown traffic, the device gave 20 false alarms in 46 minutes. (It should be pointed out, on the other hand, that in the context of a society where deaf people cannot drive, any device that satisfies the government would greatly contribute to the quality of life of deaf people.)

REQUIRED SYSTEM ATTRIBUTES

A satisfactory alerting system must have these attributes:

Reliability. False negatives would be intolerable because drivers would be dependent upon the signalling system. False positives must be reduced to a minimum, to prevent unnecessary avoidance actions by the driver, and to prevent drivers from ignoring or even disconnecting the device because of annoyance at false alarms.

Low Cost. Cost is always an important consideration. If the device is a rehabilitation technology, marketed only to hearing impaired people, its price will of course be higher than if the device is adopted as a safety requirement for all new passenger automobiles. For the latter situation to be realized, the per-unit cost would still need to be as low as possible, to make the idea more palatable to manufacturers.

Automatic Operation. The system must provide passive operation for both the driver of the emergency vehicle and the driver of the passenger vehicle. That is, the system should be automatically operational upon starting the vehicle, and the alerting signal should be transmitted without any special action by emergency personnel.

Optimal Information. The alerting signal must communicate enough information to be useful, but not so much as to be disruptive or confusing to the driver. For example, the system might provide such information as direction of sound, type of emergency vehicle, etc. Of course, as more information is added, the greater the complexity, cost, and potential for malfunction and driver confusion.

ALTERNATIVE SIGNAL CONCEPTS

There are at least three basic technical approaches to consider for transmitting and receiving the signal: Detection of an acoustic signature, detection of radio waves or light waves, and tracking using satellite technology.

Acoustic Signature. A system based on the acoustic signature of the siren is appealing because it would entail equipping only the citizen's vehicle with a device. The technical challenges of this approach include: diversity of sirens in use; difficulty of detecting the signal in competing noise from traffic and wind; and design of reasonably priced microphones or other receiving devices that could withstand the elements and still perform reliably.

Transmitted Signals. As an alternative to acoustic detection of sirens, an emergency vehicle might emit a special signal when responding on an emergency basis. Some possible candidates include infrared lights, lasers, AM radio, FM radio, and microwave signals. Infrared, laser, and microwave signals are generally limited to line of sight, and would thus have the same inherent limitations as the currently used flashing lights.

Radio frequency transmission could usefully be employed in an alerting system such as this. The emergency vehicle might carry a simple radio transmitter which would send a coded signal to passenger vehicles equipped with a radio receiving device, which in turn would activate a display. The transmitted signal would be directed ahead of the emergency vehicle.

If feasible (depending on tradeoffs in performance and cost), the signal might have an adjustable range, possibly automatically set by emergency vehicle speed. The actual range needed under various conditions remains to be experimentally determined. To avoid false positive responses, the receiving unit would need to be set to activate only when some specific level of signal intensity was reached and maintained for a specific period of time; or a frequency band might be reserved for this purpose.

The transmitted signal could communicate simple yes/no activation of the siren, or a more complex scheme could be devised in which the signals were coded for particular purposes such as direction or speed. In addition, coded signals could be used to help prevent accidents between emergency vehicles by alerting them of the approach of another responding emergency vehicle.

The major disadvantage of radio transmission is that it requires both sending and receiving vehicles to be equipped with new or modified devices. This approach increases the number of vehicles to be equipped and maintained -- with all of the corresponding policy and cost implications.

Satellite Tracking. Development over the long term might result in the use of satellite technology for tracking emergency vehicles and signalling their approach to drivers. Currently, satellite systems are used to a limited extent for monitoring the location of police vehicles. One problem with this approach is that, at least at present, users of this technology incur ongoing operational costs to lease satellite transmission capacity. Such costs would not be associated with other methods of signal transmission.

TRANSMITTING AND RECEIVING EQUIPMENT

There are many possible ways of including the signal detection device in both the emergency vehicle and the receiving vehicle. The electronics could be made part of existing equipment, developed as a separate unit, or be a plug-compatible combination of both approaches. The transmitter might need controls for transmission power and the receiver might need sensitivity controls. Both the sending and receiving vehicles would need an antenna, possibly using the existing antenna on either vehicle. In both the emergency vehicle and the receiving vehicle, the need for equipment maintenance must be kept to a minimum.

Modern emergency vehicles tend to be crowded with electronics equipment. Possible locations for placement of an emergency vehicle transmitter would be in the front grille, as part of a light bar, or built into the portable "Kojak light" often used by unmarked police cars.

Numerous options exist for placing equipment in the receiving vehicle. Possibly the device could be attached to, or become an integral part of the typical automobile radio. As always, integration has its pros and cons, and since maintenance and repair would need to be simple and inexpensive, it might be wiser to design a separate receiver.

ALERTING DISPLAY

Research is needed on the best way to alert the driver. An audio signal inside a car could distract, confuse, or impair the hearing driver's ability to listen for the direction of the emergency vehicle; and would be inaccessible to the hearing impaired driver. If a lighted display is used to alert the driver, the warning image must be in the driver's line of vision, and could be built into the windshield, or projected on the windshield; or a light-emitting device built into the dashboard, attached to the rear view mirror, or placed on the visor. If the warning signal is vibration, some possible locations are the seat, the seat belt, or the steering wheel. Care must be taken to ensure that a vibrating display would not be confused with other car vibrations.

CONCLUSIONS

Hearing impaired people have expressed the desire for a device which alerts them to sirens. In this case, their need is nearly identical to that of the general public. Development efforts in this area might eventually be rewarded with a market much larger than the hearing impaired population alone.

For such a device to have an effect on public safety, most or all vehicles would need to be so equipped. Because this is such a massive undertaking, more research will be needed on the effects of the problem, on the best ways to alert drivers, and other unresolved questions. Public awareness and support from providers of emergency services will be important to its success.

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BILEVEL VIDEO IMAGE PROCESSING AND VISUAL CONSONANT RECOGNITION

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ABSTRACT

Visual recognition of consonants was measured after reduction of the gray levels of a speaker's video image to two extremes of black and white. Two normal-hearing subjects identified VCV nonsense syllables for one speaker over a range of criterion levels for the bilevel video transformation. Initial data indicate that a range of criterion levels may exist at which lipreading performance is sufficiently good for practical communication.

INTRODUCTION

Transmission of visual speech information over telephone lines could be of value to hearing impaired individuals whose hearing loss makes telephone communication difficult or impossible. In order to make video transmission feasible for telephone lines, the information comprising the video signal must be reduced in such a way as to preserve important speechreading cues. One way to achieve this may be to reduce the video signal to a two level cartoon-like image which preserves the outlines and shapes of the speaker's facial features. With only two possible levels of gray (black or white) per picture element, just one bit of information (0 or 1) becomes necessary to identify any given point on the screen. Of particular importance in this type of information reduction is determining the criterion level of gray (breakpoint) at which a given picture element may be defined as either black or white. The photographs shown below illustrate how the choice of breakpoints affect the quality of the resulting video image. The purpose of the present study is to investigate the effects of bilevel video processing and variations in the criterion level upon visual consonant recognition scores.

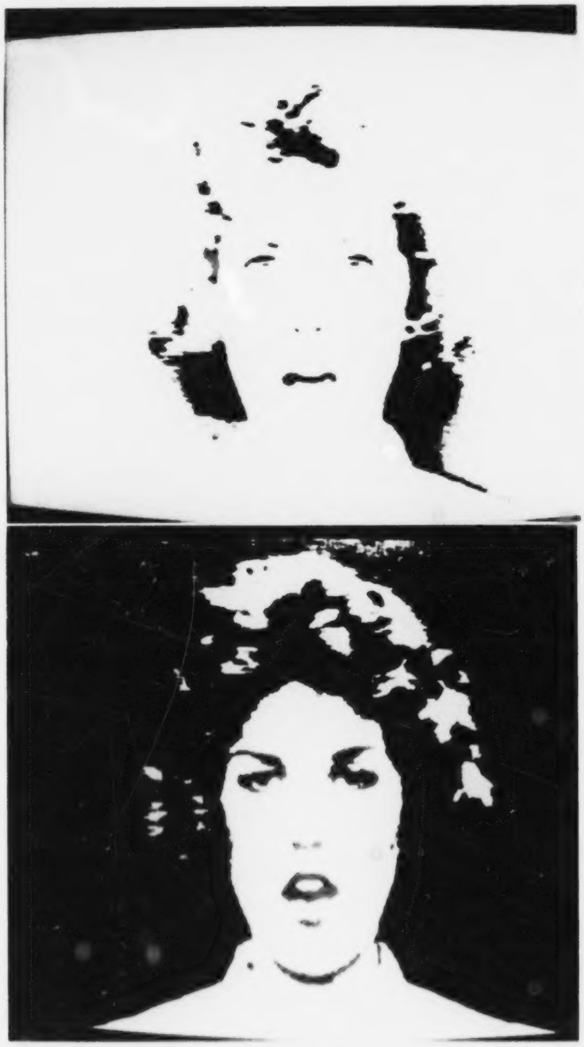

Figure 1: The top picture has a breakpoint which is too low. A higher breakpoint has been chosen for the bottom picture, for which there is less loss of detail.

METHOD

One speaker was recorded producing 69 VCV nonsense syllables consisting of 23 consonants coarticulated with /a/, /i/ and /u/. The recorded stimuli were transferred to video disk via a Panasonic Model #TQ 206F optical disk recorder, randomly sequenced, digitized and processed through a Sun microcomputer with an Imaging Technology video processing board. A total of ten test tapes were generated, one for each of nine breakpoints, as well as one unprocessed black and white video picture (256 levels of gray). After piloting with two subjects using these tapes, six of the ten conditions were chosen for more extensive testing: unprocessed, and five processed conditions with breakpoints which were chosen so as to reflect the general shape of the performance function resulting from the pilot study.

To date, two subjects have been tested. These are normal-hearing viewers whose corrected visual acuity is 20/30 or better in at least one eye, as determined by visual screening using a Snellen chart. The video testing was done at a comfortable viewing distance (five feet) from the screen of a 19" high resolution black and white video monitor in a quiet room with subdued lighting to reduce screen reflections. Subjects were instructed as to the content of the stimuli, and asked to repeat the syllable that they saw the speaker produce. Each subject was tested twice under each condition.

RESULTS

The initial results with these two subjects is shown in Figure 2. For both subjects, the syllable recognition scores for the best of the processed conditions (breakpoint 112) is only slightly below that for the unprocessed condition. Performance decreases as the breakpoints are increased or decreased relative to the optimum. It would appear that there exists a range of criterion levels at which visual consonant recognition is sufficiently good for practical communication.

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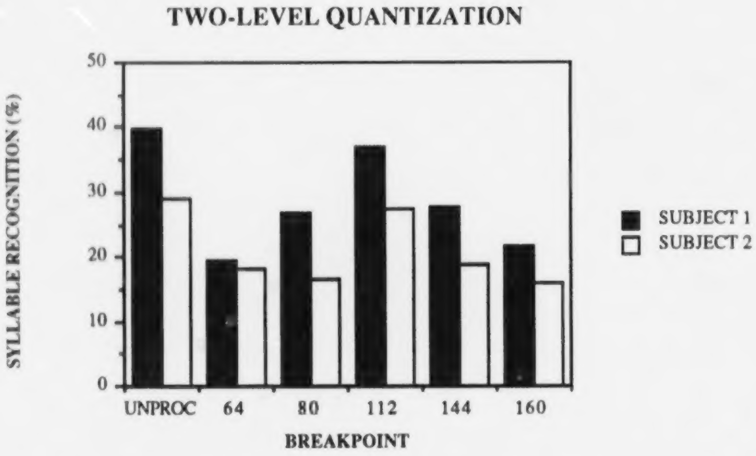

Figure 2: Syllable recognition scores for two subjects under the 6 viewing conditions. Note that the score for breakpoint 112 is roughly equivalent to that for the unprocessed condition.

VIDEO SPEECH SYNTHESIS BY CONCATENATION

Harry Levitt, Jayashree Toraskar, Matthew Bakke, Graduate School and University Center of City University of New York

Speech synthesis offers experimenters with a considerable degree of flexibility and precise control for studying the perceptually important characteristics of the speech signal. This paper is concerned with video speech synthesis for speechreading research.

INTRODUCTION

Computer techniques for the analysis and synthesis of acoustic speech signals has provided researchers with extremely powerful tools for the study of acoustic phonetics. The study of visual speech perception and the related analysis of visible articulatory movements (a field which, by analogy, should be called video phonetics) has lagged well behind acoustic phonetics largely because of difficulties in measuring and controlling visual speech signals.

An important recent development in speechreading research has been the coupling together of video and computer technology. Computer processing of video signals not only allows for extremely precise measurement, large scale data acquisition, storage and retrieval, but it also opens the door to a considerably greater degree of control over the visual speech signal. With this new technology it should be possible to address several longstanding problems in speechreading that have hitherto resisted solution.

An area of great concern is the almost total lack of data as to which physical cues in visual speech perception are perceptually important. This situation is not unlike that prevailing in acoustic phonetics prior to the development of the pattern playback speech synthesizer. The recent development of video speech synthesis as a research tool for controlling and studying the physical cues in visual speech perception represents an advance of substantial importance.

The analogy between the impact of advanced audio processing techniques on the field of acoustic phonetics with the growing impact of advanced video processing techniques on speechreading research, provides several valuable pointers regarding potentially useful avenues of investigation. Techniques such as spectrum analysis, analysis-by-synthesis, and speech synthesis by concatenation have been of great value in the study of acoustic speech perception and it is likely that these techniques will also yield rich rewards in the study of visual speech perception.

The method of speech synthesis by concatenation appears particularly promising in that it has been shown (with audio signals) to produce natural sounding speech while at the same time providing the experimenter with considerable flexibility and high precision in controlling the speech signal. This paper reports on a pilot study in which video speech signals were synthesized using the method of concatenation.

PROCEDURE AND RESULTS

Videorecordings were made of a speaker producing groups of consonant-vowel (CV), vowel-consonant (VC) and vowel-consonant-vowel (VCV) utterances. These videorecordings were stored on videodisc using a Panasonic Model #TQ 206F optical disk recorder. Pairs of syllables with a common vowel were then joined together at the midpoint of the vowel to form a set of 10 test words taken from a standard monosyllabic word list (NU List #6). For example, the syllable /mu/ was concatenated with /ud/ to produce the word mood. A trial sentence was also produced using various combinations of CV, VC and VCV syllables. Seven normal-hearing subjects participated in the study. All had normal vision, after correction with eyeglasses, as measured with a Snellen chart. They viewed the synthesized videorecordings without sound at a distance of 5 feet from a 19 inch black and white monitor (Panasonic WV 5490).

The concatenated speech was judged to be quite natural for those cases in which a good join point was found. A poor join point resulted in a perceptible discontinuity in the composite video picture. Averaging over one or more interpolated frames reduced the discontinuity but produced a slight blurring of the image.

The intelligibility of the synthesized test words (without sound) was measured for 7 normal-hearing young adults. The results are summarized the table below. The test lists were presented twice. On the first presentation, no additional information was provided to the subject. In the second presentation, some contextual information (the subject matter of the test word) was provided prior to each trial. Confusion matrices were also generated for the initial and final consonants, respectively.

The test scores and confusion matrices were found to be similar to those obtained for video recordings of natural speech. The subjects found the synthesized speech to be almost indistinguishable from natural speech for several of the test words.

CONCLUSION

The main conclusion drawn from this pilot study is that video speech synthesis using the method of concatenation is quite feasible and is very similar to a videorecording of natural speech provided good join points can be obtained between the concatenated syllables. The main problem to be addressed in future work is that of improving the quality of these join points. Improved methods of recording the component test stimuli to minimize head movements and improved methods of interpolating between concatenated elements are currently being investigated.

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Table 1. Word Recognition Scores (Percent Correct) for Synthesized Video Speech

test word	without context	with context
bud	14	71
judge	43	71
rat	0	86
gas	0	0
fame	0	14
jab	0	71
cab	57	86
mood	14	57
thud	0	57
deed	0	29
mean	12.8	54.2

ASSESSMENT OF A METHOD FOR REDUCING REVERBERATION IN AUDIO SIGNALS

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INTRODUCTION

A dereverberation processing scheme developed by Allen, Berkley, and Blauert (1) is presently under investigation. This multimicrophone technique reduces both the short- and long-delay reflections known to occur in a reverberant environment. The signal from each microphone input is first split into frequency bands. The phase differences representing the short-delay reflections are cophased and added. A gain switching function turns off the uncorrelated signals of the long-delay reflections while passing the correlated signals. The resulting signals are summed to form a single-channel output.

METHODS

In the present study, speech intelligibility tests were administered using monosyllabic words from the Modified Rhyme Test. The lists had been prerecorded at the ears of KEMAR in reverberant environments with 0.4-second and 1.2-second reverberation times. Eight of the 50-item word lists (four at each reverberation time) were digitized and then processed on the Macro Arithmetic Processor using the Allen et al (1) algorithm. The stimuli were converted back to analog and stored on audio cassettes. Another eight lists were used for testing in the unprocessed, reverberated condition.

Nine normal-hearing adults have been tested as of January, 1988. Testing was conducted in a sound-treated room at 70 dB SPL through TDH-50 headphones. The test stimuli were delivered through a Marantz cassette tape recorder connected to a Grason-Stadler 16 audiometer. Subjects were tested in eight conditions: monaurally and binaurally in the processed and unprocessed conditions at each reverberation time. Paired-comparison preference ratings were administered monaurally for the processed and unprocessed stimuli at the two reverberation times.

RESULTS

Percent-correct scores from the Modified Rhyme Test are displayed in the table. These scores were subjected to a three-factor analysis of variance. Results revealed statistically significant main effects for the monaural vs. binaural conditions and for reverberation time. Scores in the binaural condition were significantly higher than scores in the monaural condition ($F=9.926$, $df=1,8$, $p<.02$). Scores at the 0.4-second reverberation time were significantly higher than scores at the 1.2-second reverberation time ($F=200.116$, $df=1,8$, $p<.001$). The effect of processing was not found to be statistically significant, although there was a significant interaction between binaural vs. monaural conditions, reverberation time, and processing ($F=13.94$, $df=1,71$, $p<.006$). At the 1.2-second reverberation time, the binaural/monaural difference was found to be greater in the unprocessed condition.

Nonparametric analysis of the paired-comparison preference ratings indicated a statistically significant preference for the processed condition over the unprocessed condition at the 1.2-second reverberation time (Wilcoxin Matched-Pairs Signed Ranks Test, $T = 2$, $p<.005$). The ratings at the 0.4-second reverberation time were not found to be statistically significant. Subjectively, the subjects reported a consistent dislike for the highly reverberant condition when paired with the other conditions.

These results are in agreement with those reported by Bloom (2). Testing of this processing technique is currently in progress with hearing-impaired adults.

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ACKNOWLEDGEMENTS

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MODIFIED RHYME TEST
PERCENT CORRECT

(U = Unprocessed, P = Processed)

	Monaural Condition				Binaural Condition			
	Reverberation Time				Reverberation Time			
	0.4 sec		1.2 sec		0.4 sec		1.2 sec	
Subject	U	P	U	P	*U	**P	*U	**P
1	96	90	78	84	94	90	92	82
2	98	92	92	90	96	94	90	84
3	92	96	82	88	100	100	86	86
4	98	92	84	88	96	96	84	88
5	96	96	78	82	100	96	94	90
6	96	94	88	80	96	98	90	88
7	98	92	72	76	92	96	84	92
8	98	92	88	72	98	100	94	88
9	98	100	84	92	100	96	98	84
X	97	94	83	84	97	96	90	87

*Dichotic
**Diotic

AN EVALUATION OF A REAL-TIME SPEECH PROCESSING AID FOR THE HEARING IMPAIRED

Richard G. Stoker, School of Human Communication Disorders, McGill University;
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INTRODUCTION

Many devices and schemes have been proposed over the past 25 years to improve speech reception by the hearing impaired [1,2]. In general, they attempt either to circumvent the hearing loss by substituting another sense (e.g. vision or touch) or to assist the deficient auditory sense by presenting the acoustic signal in a different way. For sensorineural hearing loss, the recoding of inaudible speech information into the low frequency region where most residual hearing is present, is the most natural and theoretically one of the effective ways to **assist** the impaired cochlea. In this paper we report an evaluation of a highly promising speech processing aid based on this latter approach.

THE LEE-BADDELEY SYSTEM

Recently, Lee and Baddeley [3,4] reported the development of a microcomputer-based, real-time system that effectively encodes high frequency speech cues such as frication and formant energy into the frequency region below 1kHz while maintaining the natural time-intensity cues critical for perception of stress, intonation and juncture. The system consists of analogue and digital electronic circuits controlled by a microcomputer. Adaptive analogue filters extract high frequency formant and frication signals continuously in real time. The outputs from these filters are processed by the surrogate generators to produce sounds in the residual hearing range. The amplitude of the output of each surrogate generator is made to follow the output of the filter such that important temporal information is preserved and the resulting sound is speech-like. The formant and fricative surrogates are mapped into the hearing range according to an algorithm that avoids interference to the first formant and attempts to reduce masking effects. The parameters for the mapping operation are updated continually at 7.5 millisecond intervals on the average. Technologically, the system is a substantial improvement over earlier attempts, as it has overcome many drawbacks reported in the literature.

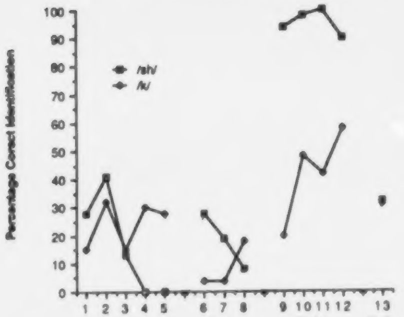
METHODS

The evaluation was carried out using a replicated single-subject, alternating treatments design [5-7].This experimental design eliminates the problem of many possible confounding subject variables because the subject serves as his own control. It is also an appropriate design for this kind of study where use of a reversal design (in which the subject would be taught an identification strategy, then "retaught" a completely different strategy) would be undesirable. Two target phonemes were identified,(/ʃ/ and /k/), using the Nonsense Syllable Test (NST) which the subject was unable to perceive through audition. These two phonemes differ significantly in place and manner of production, so it was felt that training in one would not "contaminate" perception of the other. A probe test was constructed to evaluate gains in the ability of the subject to perceive the target phonemes. The probe consisted of a closed set identification of CV and VC syllables (30, 5 element sets) and a set of 36 words containing the target phonemes and foils. The probes were used to evaluate baseline performance of the subject on the target phonemes in a variety of contexts and performance as training progressed using the speech processing system. Data was reported as percentage correct identification of the target phonemes in all contexts.

RESULTS

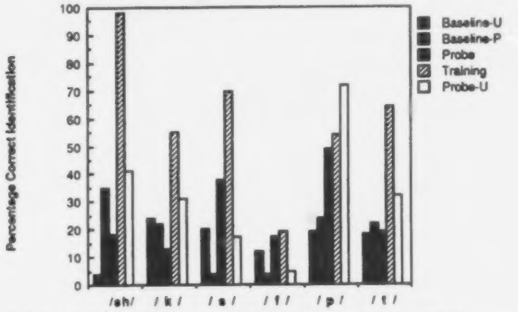
As can be seen in Figure 1, There were observable gains from the baseline

Figure 1. Percentage Correct Identification as a Function of Condition for /sh/ and /k/



performance to the end of the fourth training session, with the subjects ability to identify the target phonemes improving approximately 80% for /ʃ/ and 40% for /k/. A final probe performed without the speech processor showed that performance fell to levels approximately equal those of the baseline. Additionally, Figure 2 shows that some of the sounds used in training as foils also showed improved perceptibility with training. In particular /s/, /t/ and /p/ showed remarkable gains (32, 41 & 22 % gains respectively).

Figure 2. Percentage Correct Consonant Identification as a Function of Stimulus Condition



DISCUSSION/ PRELIMINARY CONCLUSIONS

Our results so far indicate that the speech processing provided by the Lee-Baddelly device is capable of producing improvement in discrimination of syllabic level phonetic information in phonemes with significant high-frequency information. The gains observed over the course of training point out the need for intensive training in the use of such devices. It is also of interest that sounds not specifically trained (e.g. /s/,/p/,/t/) showed impressive improvements in perceptibility. This indicates that incidental learning of the discrimination cues is possible. Of course, replication of this study with more hearing impaired listeners will be necessary to confirm the generalisabilty of the process, especially as it pertains to running speech. It is encouraging, however, to note that relatively short-term training produced quite dramatic improvements in syllabic discrimination of a notoriously difficult sound for hearing impaired individuals (/ʃ/). Further studies, utilizing word and phrase-length material are planned to explore further the general usefulness of the device.

ACKNOWLEDGEMENTS: The authors wish thank Yves Beauregard for his assistance in carrying out part of this study.

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"SPECIAL INTEREST GROUP". 9

Wheeled Mobility & Seating
Mobilité et positionnement en fauteuil

DEVELOPMENT OF A WHEELCHAIR-ACCESSIBLE WEIGHT-TRAINING APPARATUS

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The Hugh MacMillan Medical Centre, Toronto, Ontario Canada and *Variety Village Sport Training and Fitness Centre, Ontario, Canada

INTRODUCTION

Most weight-training equipment available commercially are geared toward facilitating the body-building and conditioning requirements of able-bodied individuals. While the equipment available is extremely versatile in conditioning a wide range of muscle groups for some, limited use of the equipment is possible for most wheelchair users.

Issues such as wheelchair inaccessibility, awkward equipment adjustments, unstable support surfaces for users and user interfaces which are out of reach and require assistance from others, often lead to user frustration and discouragement. While conditioning stations are relatively safe to operate, they are inefficient in optimizing training time for disabled athletes who must transfer from wheelchair to bench. Also, close supervision is required especially when free weights are used. Of concern to athletes involved in specific competitive sports is the need to "make do" with certain equipment which may not work muscles in an appropriate or controlled way.

DESIGN DESCRIPTION

In an effort to provide a reliable means for optimizing training time for wheelchair athletes, a multi-adjustable, single-station weight-training apparatus was developed. It incorporates some of the functional features of commercial multi-station gyms and the "feel" of using free weights with the added advantage that safe operation is possible while the user is seated in a wheelchair.

The apparatus consists of a free-standing tubular steel frame, a press bar, an adjustable press bar guide, two selectable weight stacks, two pulley sets, and a user securement system (Figure 1).

The frame is constructed of 2 inch diameter tubular steel and is configured to allow the user to enter at the rear of the device in a wheelchair and remain in it while lifting weights.

At the front of the frame is a weight press bar guided by Delrin bearings on two parallel thick-walled tubes which pivot on hinges about 30 inches above the floor. The guides preclude user injury caused by inadvertant loss of control of the press bar.

Two locking gas springs, actuated by specially-designed release handles, are attached to the guides to offset their weight. The gas springs also serve to facilitate angle adjustment of the press bar guides from an orientation directly vertical to any angle up to 10° above the horizontal. This adjustment, as well as adjustments to the amount of weight pressed, can be made with the user secured in a single position. Press bar guide adjustment allows shoulder presses, chest presses or proportional combinations of the two to be performed. Additionally, back and abdominal muscles may be worked by locking the elbows and pivoting about the hips.

Weights are applied to the press bar through a cable/pulley arrangement by two sets of weight plates, one on each side of the user. Modified weight stack adjustment pins are used to permit athletes who have weak grips or limited fine motor ability to use them.

The user is secured in place at the knees by an adjustable, padded safety guard and at the back by an adjustable tension automotive belt assembly.

ASSESSMENT

The apparatus was on trial for three-and-one-half months at the Variety Village Fitness Centre in Scarborough, Ontario where eight adult wheelchair atheletes used it regularly. Participants included four paraplegics (one being a post-polio case, another having a crushed vertebrae at T7, one having spina bifida and another having a spinal disorder of an unknown nature). Others participating in the study were a leg amputee, a user with multiple sclerosis, one with cerebral palsy, and another with equilibrium problems related to neurosurgery complications.

At the end of the field trials, each participant completed a 15-point questionnaire which recorded the frequency of use, the range of adjustments and the frequency of adjustments. A number of questions relating to system performance were also posed.

Additionally, all respondents were asked to assign numerical ratings to the performance of the equipment on a scale of 1 to 5, where 1 was an indication of poor performance and 5 was an indication of excellent performance.

RESULTS

All participants used the equipment one to three times per week on the average. All found it to be very easy to enter the machine and position themselves. All users reported that they used the restraint belt/ safety guard system to secure their wheelchairs. While five reported that no assistance was required to fasten and adjust the belt, the user with multiple sclerosis noted the staff instructor provided assistance sometimes and both the user with spina bifida and the respondent with equilibrium problems said they could not do this without help.

Seven participants reported that no assistance was required to adjust the press bar guide while the user with multiple sclerosis noted that the instructor adjusted it for him. All respondents indicated that no assistance was required to adjust the amount of weight pressed.

In considering these adjustable features, all reported the adjustments to be at least fairly easy to make.

Five reported that once the press bar guide was adjusted during a session, they did not adjust it again, while the other three reported that they did up to three times on average. All participants noted the range of weights provided to be adequate. Additionally, all reported the machine to be structurally sound and the components to be durable.

Six users felt that the apparatus was very safe to operate while two indicated that it was fairly safe. Some concern was noted in the area of back support while performing near or full shoulder presses.

All reported the appearance of the device to be at least fairly acceptable. All reported that they would use the device regularly once it was released for general use at Variety.

The average ratings assigned for each of six categories are provided below:

Performance Catagory	Rating Out of 5 (average)
1. Ease of Adjustments	4.5
2. Range of Adjustments	4.4
3. Structural Soundness	4.9
4. Safeness of Operation	4.9
5. Appearance	4.3
6. Overall Usefulness	4.4

CONCLUSIONS

Its evident from the results of the assessment that the device was well-received. Indications are that the goal of providing a safe, serviceable weight-training system which would directly benefit a large number of disabled persons at Variety Village was met.

ACKNOWLEDGEMENTS

This project was funded by the Variety Village Sport Training and Fitness Centre. Special thanks go to Ron Thompson at Variety Village for providing valuable input during the design phase of the project.

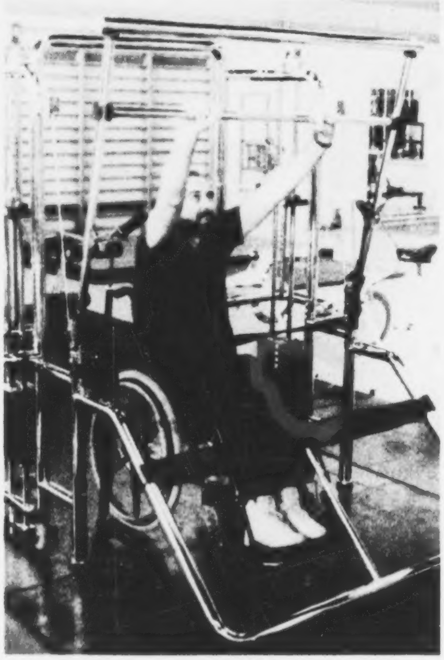

Figure 1 - Wheelchair user pressing weights in weight-training apparatus.

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THE DESIGN OF A CRIB FOR USE BY PHYSICALLY DISABLED PARENTS

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INTRODUCTION

Conventional infant cribs present difficulties to a wide group of physically handicapped persons. Those with upper-extremity weakness can have problems in unlocking the crib and lowering the sides. Lifting the infant over the lowered side may require too much exertion for many persons. A group who find conventional cribs particularly challenging are those who use wheelchairs. When the side of the crib is lowered, the wheelchair-bound person is forced to move back or turn sideways. Both strategies are inconvenient and are potentially hazardous to the infant.

The work reported here was aimed at designing and constructing a crib which could be handled by physically disabled persons but which would give the infant the same protection as is afforded by conventional cribs.

METHODS

Prior to designing the new crib a careful study was made of existing devices and of Canadian Federal Government regulations for cribs and cradles (1). These regulations, produced by Consumer and Corporate Affairs, Canada, cover hazards related to: "mattress support systems, structural integrity, small parts, and slat strength and spacing" (1). Special emphasis is given to the structural integrity of the crib, which must withstand very rigorous testing.

It became clear early in our work that significant advantages would be achieved if, rather than designing a new crib, we modified existing commercially available units in a manner which did not degrade their structural integrity. The advantages of this strategy were in terms both of cost and safety. With much of the structure of the original crib left untouched, we were able to concentrate on the changes which we made to make the cribs more accessible to physically handicapped persons. Increasing accessibility could increase the risk of accident to the infant. Consumer and Corporate Affairs' regulations were a guide in avoiding any such problems.

DESCRIPTION OF NEW CRIB

The newly designed crib is shown in use in Figure 1. A standard crib was modified in the following way:

1. The crib was raised so that the knees of a wheelchair-bound person would fit underneath.
2. The fixed side of the crib was modified by equipping it with sliding doors (opened by the simultaneous activation of two latches).
3. The mattress support was left permanently in the lowest position.
4. The upper horizontal support, which had to be left intact for structural reasons, was padded to protect the infant's head while being transferred in and out of the crib.
5. A special barrier is automatically in place when the doors are opened to prevent the infant from accidentally rolling out.

EVALUATION

A prototype of this crib has been undergoing tests in actual use for the past several months. The wheelchair-bound mother found it very easy to use and was in no danger of hitting the infant's head when putting him in or out of the crib. The father, who is ambulatory, could lower the opposite side of the crib and remove his son normally. Minor problems which are currently being addressed involved difficulties in changing the sheets, since there was no access on the modified side, and difficulties in attaching bumper pads to this same side.

DISCUSSION

This new crib has been very successful, primarily for the following reasons:

1. The basic structure of an existing standard crib has been left intact. As a result, it was fairly easy to insure that all regulations laid down for cribs by Consumer and Corporate Affairs were met.
2. The crib was raised by 34 centimetres to allow a person sitting in a wheelchair to slide their knees underneath and reach the infant safely.

3. The design was made so that the base and mattress remained at the lowest position. This meant that no changes had to be made as the child grew up.
4. A non wheelchair-bound person could lower the other side of the crib to pick up the infant. This is an important feature since the top bar of the side which slides open remains in place and the infant could bump his or her head against it while being moved in or out by a standing person.
5. Additional safety features (such as the inside set up doors and precautions to prevent the infant climbing on any added components) make this a very safe crib.

Information on the availability of this new crib can be obtained by contacting the Rehabilitation Engineering Department at The Rehabilitation Centre in Ottawa.

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Published in Canada Gazette part 2, Vol. 120, No. 20, p. 4124-4135.

ACKNOWLEDGEMENTS

The authors acknowledge the contributions by: Louis Goudreau, Ray Cheng, and Harold Gay. The operational testing of the crib was done by Joe, Kate, and Anthony Paialunga.

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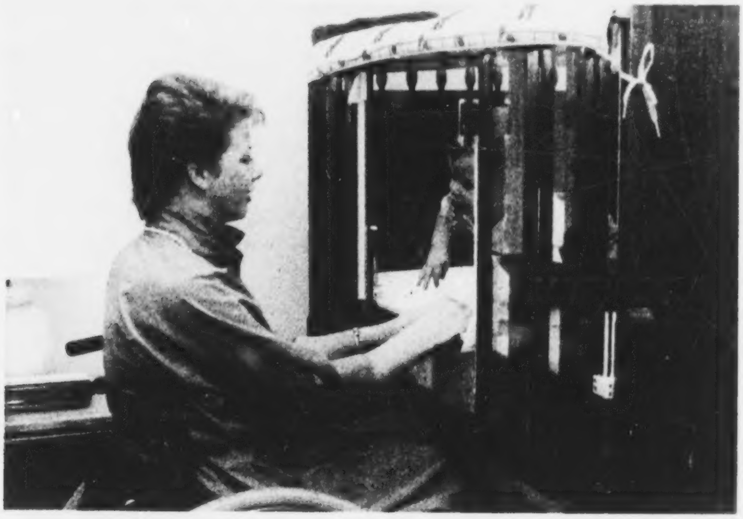


Figure 1. Crib in use by wheelchair-bound parent.

THE MARSMOBILE - AN ADAPTED BICYCLE FOR PUSHING WHEELCHAIRS

Don Marsland - Mackay Center, 3500 Décarie, Montréal, Québec.

The Marsmobile is a modified bicycle. It can connect to the back of most manual wheelchairs, to be used as an alternative propulsion device, by a secondary user for pushing the wheelchair.

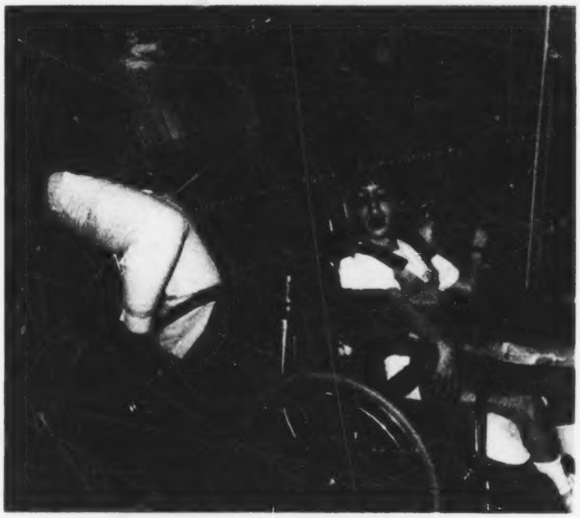
INTRODUCTION

The bicycle attachment was developed in June of 1987, at the Mackay Center. The project was invisioned by a parent of a severely involved Cerebral Palsy child. He was looking for a way to attach a bicycle to the back of his daugther's wheelchair to take her for rides and give them another form of mutual activity. This was very important to him as their activities together are very limited. Another reason for the development of this device, is that this child needs a great deal of positioning in her wheelchair to be properly seated. So the inconvenience of folding the wheelchair and putting it in the car would be eliminated to go short distances. Places too far to walk, but accessible by bike, would be attainable with this attachment. Examples of this would be going to the park, the shopping center or to visit a friend. By attaching the bike to the back of the chair the parent or friend could ride the disabled person anywhere they desire, disconnect the bike when they arrive and walk behind the chair again.

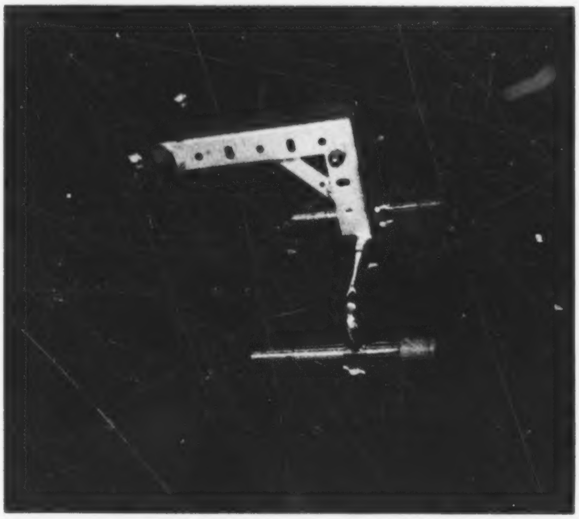
METHODS

In developing a system for this purpose, the parents of the child, gave us a slightly used ten speed bicycle with a low horizontal tube between the handle bars and the seat. The first step in the design process was to remove the front wheel of the bike and look for some type of interfacing device to attach the bike to the wheelchair.

A lower unit was developed using tubular and angled steel, welded together to form a configuration that fitted on to the axle bolts and the tilting tubes of the wheelchair. Then the front forks of the bicycle slide into an axle unit on to this interfacing



Father and daughter, going for a ride



Lower attachment unit

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device. After connecting the bike to the chair we encountered a few problems;

1. The distance between the pedals of the bike and the rear wheels of the wheelchair would touch on sharp turns.

2. The castering action of the front forks of the bike would cause the bike to lean away from the wheelchair when turning.

3. Having just the lower unit was not a ridged enough interface, which made the unit unstable going over uneven terrain.

On the second proto-type the lower unit was extended length wise to create enough space between the pedals and the rear wheels of the chair. The caster effect of the front forks was eliminated by cutting the horizontal top tube between the handle-bars and seat and opening up the angle of the steering case until it was perpendicular to the ground. Then the handle bars were cut, to leave just a straight tube of approximately six inches. Another tube was press fit through remaining handle bars and modified brackets mounted onto either end of this unit. The modified brackets then fitted directly inside the handles of the wheelchair. This locked the bike into a ridged structure with the chair, and also provided a means of adjusting the amount of weight excerted on the front casters of the wheelchair. At this point the bike/chair unit was functional for trial purposes.

RESULTS

On this first model, we are very pleased with the initial results. Control and maneuverability seem very responsive and easy to handle, but braking was and still is a major concern. With just a single caliper type brake on the bike rear wheel, there is not enough power to stop the device in an emergency situation. Also the rear wheel itself is not ridged enough. A solution to this would be to use an 1 1/2" or an 1 3/4" tire, with heavy duty spokes and coaster brakes.

Another important point is the weight ratio between the passenger and driver, and the amount of weight load exerted on the wheelchair casters. With a child (passenger) of 50 lbs and a driver of over 150 lbs, the front casters could be raised completely off the ground and there is no concern of caster shimming. However as the weight ratios increase and equalize, the casters would become a problem over speeds of 6 to 8 mph.

We found this unit was easily modified to fit any size manual wheelchair of Everest & Jennings design. From the smaller Junior sizes to largest of adults, the unit adapted easily and was enjoyed by everyone who tried it, driver and passenger alike.

CONCLUSION

In conclusion the Marsmobile could have broad applications as a functional and recreational tool. We feel that this type of device could improve the quality of life for a lot of wheelchair bound individuals.

BIOCAR FOR CRAWLING AND PLAYING AT FLOORLEVEL

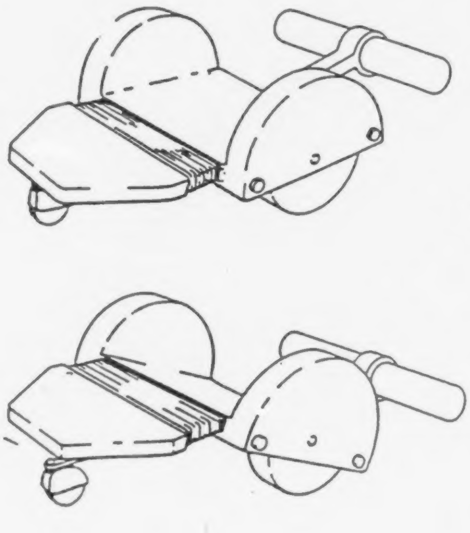
H.G. Berghauser Pont, Prof. Ir. J.J. Jacobs, C.M. van Ooij,
Ir. D.J. van Eyk

Despite of the variety of mobility aids for the handicapped, most of these aids have one thing in common; a tubular chrome-plated frame with blue imitation leather upholstery.
However, there is a tendency towards a more modern approach in the design of these aids. Especially for children some good looking carts, made of colorful plastics, are now available on the market. But ideally, all mobility aids, including the more complicated ones, must not only function well but also have a nice appearance.

The Biocar-project aims to develop a new generation of mobility aids for disabled children. The three partners in the Biocar-project are: The Bio Rehabilitation Centre for children, the faculty of Industrial Design of the Delft University of Technology, and the Linido Company, producer of aids for the disabled.
Suitable mobility aids will have a positive influence on the development of the handicapped child. Independent mobility will help the physically impaired to get new experiences, to play with peers and will increase their motor and control development.

In order to classify the mobility aids that are needed, a population survey was carried out, including the functions that a product would have to fulfill. Four groups of users can be distinguished. Each group has its own implications in relation to the propulsion and the steering of the aid. The functions to fulfill are: crawling, playing at floorlevel, activities of daily life and moving around over some distance.
The combination of the four groups of children and the four functions to fulfill leads to sixteen specific needs.

To start with, a mobility aid for both crawling and playing at floorlevel has been taken as far as the prototype stage. It is intended for the child that can use its arms for propulsion and steering.
The users of such an aid are up to eight years old. The aid has the appearance of a toy, is adjustable for that population of users and can be adapted to different prone lying and sitting postures.
In between the age of 2 and 6 years old it is necessary to develop a mini- and maxi-sized type to cope with the body dimensions of the children.
Based on the experience gained with this prototype, other types will be developed to create a new generation of mobility aids for disabled children.
Sponsoring by National Program of Innovation of Aids for Disabled in the Netherlands.



SUMMARY

The subject of the Biocar-project is the development of a new generation of mobility aids for the disabled children.

Population survey and analysis of functions of fulfill learned that four groups of users can be distinguished in relation to:
- crawling
- playing at ground level
- activities of daily life
- mobility over some distance

The project is a collaboration of a Faculty of Industrial Design, a rehabilitation centre and industry.

The first part of this project, concerning the design of testing of mobility aids for playing at ground level, will be presented.

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I.W.K. Children's Hospital Fitting Frame

J. Weidhaas and M. Lloyd

The I.W.K. Children's Hospital is a 260 bed tertiary care facility serving the paediatric population of Canada's Maritime Provinces. The occupational therapy department began in 1976. In 1978, in response to a perceived need the remedial seating program was started. The program initially serviced children in New Brunswick and Prince Edward Island as well as Nova Scotia. There are now two smaller programs in Fredricton, N.B. and Charlottetown, P.E.I. which serve most of the children living in those provinces. The present caseload is about 450 - 500. Our program is self-supporting, not provincially funded, and our personnel resources are limited. The need to look at the efficiency of our seating technologies was precipitated through the size and location of the population served as well as our limited personnel resources.

The caseload of the program consists of approximately 80% cerebral palsy (primary diagnosis) with the remaining cases diagnosed with neuromuscular disease, spina bifida and other conditions (such as osteogenesis imperfecta). Our present technologies for seating include foam and plywood (simple and complex), custom-contour (contour-U) and hybrid systems. These seats are mounted on a variety of bases including manual and power wheelchairs, stroller bases, scooters and carseats. The criteria for technology choice include assessment of neuromotor and orthopaedic status as well as the areas of client functioning, including use of the seat at home and school and caregivers' attitudes towards the seating system. As there is no provincial government program for funding these systems we must also carefully examine funding available before technology choice is made.

The traditional process of assessment for foam and plywood technology including: orthopaedic and neurological assessment of the child, taking body measurements on a bench, taking base measurements, building a prefit and fitting with one or more revisions was questioned in terms of time and cost efficiency. Final products from this assessment and fitting method were questioned in terms of meeting overall client needs. There appeared to be a necessity to address such variables as the effect of recline and various back to seat angles on the child's position. The traditional method would only permit this to be done by trial and error through measurement, prefit and revision stages (the final two stages being repeated more than once in difficult cases). Because of the travel distances involved for many of our clients and the limited number of personnel to serve these clients, the traditional assessment and fitting process was deemed inefficient as a means of service delivery. These factors led to the development of the fitting frame. It is a multi-component adjustable simulator which allows us to answer some of the "what if" questions during the initial assessment of the client.

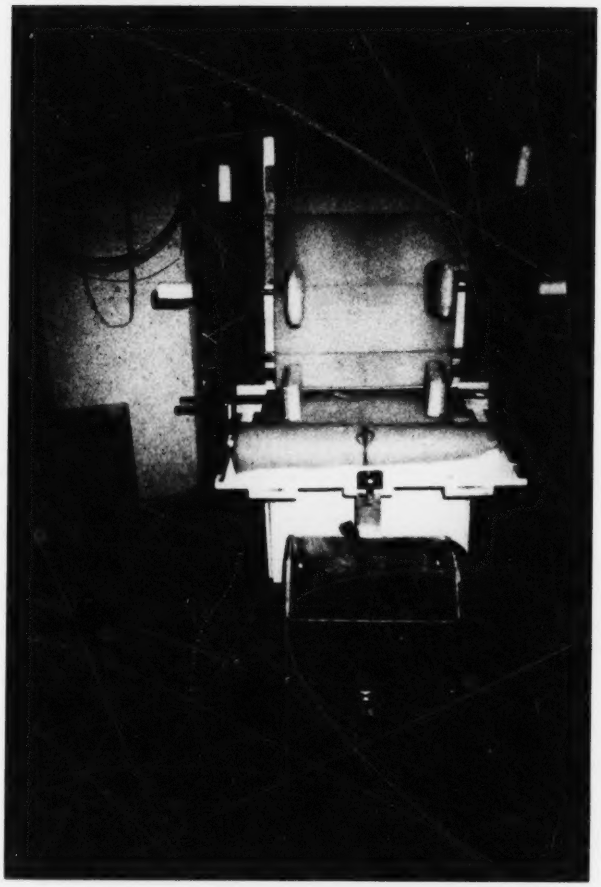
SPECIFICATIONS OF THE FITTING FRAME

ADJUSTMENTS

Seat-depth from 3" to 24"
Back-height from 6" to 24"
Back-to-seat angle from 90° to 160°
Orientation in space from 0° to 30°
Fully adjustable lateral supports, hip and/or knee blocks and shoulder blocks
Height adjustable tray and footrest box

Allows for trial of various wedges and anti-thrust blocks; as well as different thickness and types of foam
Accepts various pummels in the traditional pummel mount; pelvic and chest straps and butterfly chest panels; traditional foam and ply headrest bracket as well as Ottobock brackets and the Hensinger neck support
The fitting frame is portable and self-contained.

The fitting frame has proven itself in both time efficiency and in providing seats which were better able to meet multiple client needs. The poster presentation describes the simulator and its components and how it has proven to be an effective tool for the assessment and provision of foam and plywood technology.



USE OF A POSITIONING CHAIR IN CONJUNCTION WITH PROPER SEATING PRINCIPLES FOR A SEATING EVALUATION

Faith Saftler, PT   Jody Winter, PT   Kelly, MA, PT

ABSTRACT

Use of a positioning chair can be an effective tool in the evaluation process when determining the wheelchair needs of the physically involved individual. After initial mat measurements are obtained, the positioning chair is set up to the individual's dimensions and needs. The individual is then placed in the positioning chair and proper placement of supports is addressed to achieve optimal positioning. Linear and angular dimensions are finalized for improved accuracy. Final review of the individual's goals can be addressed at this time while maintaining an optimum seating position. Following are seating principles which can be used during the evaluation process. These seating principles should be used during the mat exam as well as in the positioning chair to assist the individual in obtaining the most optimal seating system.

INTRODUCTION

Specific seating principles and a positioning chair have been used for evaluation purposes since 1984 in the State of Florida. These concepts were first developed and used at the Fernald State School in Massachusettes. The following principles are necessary to understand before seating a physically disabled individual. This paper discusses each principle in conjunction with the positioning chair and their effect on an individual's sitting posture.

METHODOLOGY

Provide Firm Surfaces For Support

Areas of the body perpendicular or near perpendicular to the line of gravity are more important weight bearing areas and require firm support. Areas that are less perpendicular to gravity are less important as weight bearing areas.

The positioning chair provides a firm seat, firm back, foot support, arm support, and head support. These can be adjusted to an individual's linear dimensions.

Stabilize Pelvis In A Level, Derotated, And Slight Anteriorly Tilted Position

This pelvic position is the base for normal skeletal alignment allowing for control of the upper body and greater trunk range of motion. This position also allows for equal weight bearing on the ischial tuberosities rather than on the sacrum and assists in preventing skin breakdown.

Maintaining this optimal position allows for co-contraction of trunk muscles for facilitation of active trunk control without putting the extensors on stretch and abdominals on slack. Providing extension in the low back and flexion of the hips will assist in breaking up spastic patterns.

A seatbelt attached to the positioning chair is used to stabilize the pelvis. Linear and angular dimensions can be altered to assist in achieving a level and derotated pelvis.

Key Seating Angles (hips, knees, ankles) Must Be Individually Determined For Each Person Based On Available Joint Range Of Motion

Key seating angles need to be determined during the mat exam. The pelvic position must be maintained while moving all other body parts. The goal for the hips is 80° - 84° hip flexion which translates to 96° - 100° seat to back angle. In the normal population, a seat to back angle of at least 96° is required to maintain the center of gravity of the body directly over the pelvis. A 90° seat to back angle actually throws the center of gravity forward of the pelvis requiring the back extensors to work to maintain an upright position.

Therefore, 96° should be the most acute seat to back angle used.

The goal for the knees is -90° of knee extension which translates to 90° seat to calf angle. The hips are maintained in the above position while assessing the knee range of motion.

The goal for the feet is a neutral position of plantarflexion & dorsiflexion which translate to 90° calf to foot angle. The 90° angle at the knees and ankles in upright sitting places the lower extremities in the optimal position for weight bearing and stability.

The positioning chair has an adjustable seat to back angle, seat to calf angle and calf to foot angle.

Provide Optimum Alignment
After stabilizing the pelvic position, aim for neutral alignment in all other body parts. If neutral alignment can not be achieved, determine the flexible component of the deformity. Start in the maximally corrected position and then back off slightly to avoid problems associated with overcorrection. Always accommodate for the fixed component of deformities.

The positioning chair has fully adjustable trunk supports, medial and lateral thigh supports, and hip pads to provide optimum alignment. Back and seat molding systems can replace firm seat and back sections.

Limit Abnormal Movement In Order To Facilitate Normal Movement
Provide appropriate surfaces to prevent undesired movement patterns. You must first determine what movement initiates the abnormal pattern. Then, prevent that initiating movement only. Now you can determine if additional surfaces are required. Always provide ample time for development of desirable new movements.

Analyze The Potential Effects Of Gravity On All Body Parts, Then Use This Force Advantageously
Gravity is a very powerful and constant force which can effect both positive and negative changes in the body. Gravity plays a major role in the development of many deformities and in the prevention of movement or skill acquisition.

Through the strategic placement of supports, body parts and angle of orientation, it is possible to put this important force into positive action. In this way, gravity can be used to limit undesired movements and facilitate weak or absent movements. Specific positioning can utilize gravity to increase joint flexibility.

The positioning chair can be angled in space while maintaining all angles.

Stabilize Proximal Body Parts To Allow For Improved Distal Mobility And Function

Provide The Minimum Amount Of Support Necessary To Achieve Stated Objectives
By providing the appropriate amount of support, you should be facilitating the acquisition of skills to foster independence.

You may facilitate independence from equipment rather then creating new dependence on equipment or provide additional support to promote independence in the use of equipment and technology.

Provide ample time, encouragement and opportunity (ie. programs) for the development of new movements before adding more restrictive supports.

SUMMARY
With continued use of these principles in conjunction with a positioning chair, a more therapeutic approach to seating can be established with the physically disabled individual. Therapists and vendors can systematically achieve optimal positioning with the individual while addressing their therapeutic goals and allowing for interaction with their environment.

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INDEPENDENT WHEELCHAIR MOBILITY FOR KEVIN: A TWO YEAR OLD OXYGEN - DEPENDENT CHILD

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INTRODUCTION

This case study presents the vital rehabilitation issue of independent mobility for preschool children. It has been shown that young children who are deprived of independent movement do not achieve optimum perceptual development. It is therefore part of the philosophy of rehabilitation at the Hugh MacMillan Medical Centre to encourage independence. Another study (1) has dealt with this subject in detail.

This paper describes the provision of a wheelchair that holds suction and oxygen equipment. It is unique in that it was designed for an oxygen dependent preschool child who is being integrated into the community. The system allows him to propel himself thus encouraging his perceptual & cognitive development. It folds for transport in the family vehicle and is safe in a wheelchair bus. His mobility has made it possible for him to attend an integrated preschool.

Background

Kevin is a 3 year, 9 month old (DOB 23/9/84) with a primary diagnosis of Spina Bifida with a tracheostomy secondary to a decompressed Arnold Chiari malformation. He was admitted to the Hugh MacMillan Medical Centre in June, 1987 for rehabilitation. Following multidisciplinary assessments and interventions, he was presented to the Seating Clinic by the occupational therapist, with the following issues:

1) Kevin has independent sitting balance and is physically able to manipulate a manual wheelchair.

2) He is a sociable responsive child who, due to his medical problems, has been hospitalized much of his life.

3) Kevin has sudden and potentially fatal onsets of apnea. Therefore he cannot be left unattended and immediate tracheostomy suction and oxygen must be administered.

4) Discharge plans include his living at home with his parents and attending a community preschool.

METHODS

Initially, the equipment needs were identified as follows:

1) A size-appropriate, lightweight wheeled base that Kevin could manipulate and brake independently.

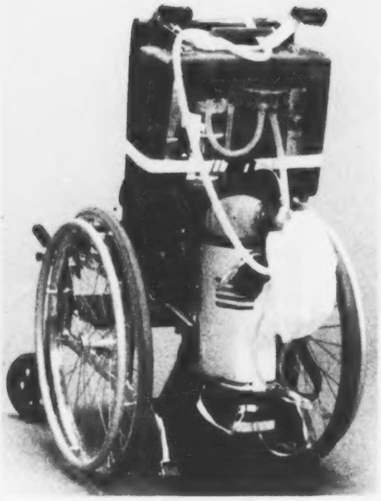
2) A suction machine, liquid oxygen and oxygen tank immediately available to his caretakers.

3) The ability to recline/tilt him backwack to a 45 degree position during suction and oxygen administration.

4) The transportability of the system both in the parent's automobile and in the wheelchair bus used by the school.

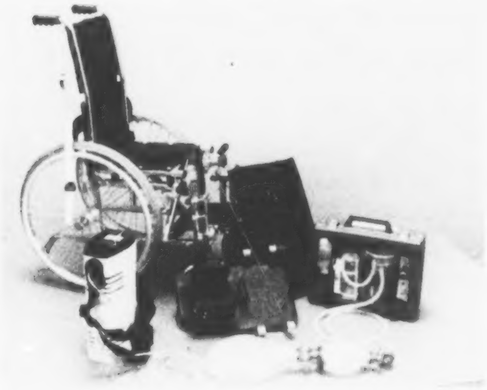
The wheeled base chosen was the E & J Premier 2. It was ordered with a 12" x 12" seat and an 18" high back in order to support his shoulders and head when in the backward tilted position. There is space available between the back uprights and under the cross bars for the special equipment. The wheelchair weighs 23 lbs., and with the aluminum wheels, moves freely. A one-inch cushion was fabricated of polyfoam to position his shoulders in line with the wheels for more efficient self-propulsion. Footplate extensions were also built in order to support his feet while keeping his knees at 90° of flexion. Safety straps were added.

The portable suction machine (Laerdal Suction Unit) is held by 'L' brackets attached to the wheelchair uprights, two straps over the push handles and a 1" strap around the whole. The portable oxygen container (Liberator/Stroller) sits on a plywood base suspended on the wheelchair tipping levers (Figure 1). Straps and side brackets secure it. The oxygen tank was not required as originally thought since his medical condition had stabilized.



(Fig. 1)

The special equipment is easily removed (Figure 2). The wheelchair folds and with wheels and footrests removed, weighs 23 lbs. for easy stowing in the family automobile trunk. It is a standard configuration that can be restrained in a wheelchair bus using the Q-straint system of transport tie-down.



(Fig. 2)

DISCUSSION

Kevin demonstrates ability and interest in wheeling himself. Although someone trained to administer suction and oxygen must be with him constantly, his caregivers respect his independence.

He is medically stable enough and his family comfortable enough with his special needs that he spends weekends and holidays at home. Since January, 1988, he has been attending a community-based integrated preschool every morning. He continues to live at the Centre during the week.

CONCLUSIONS

The acute medical needs of the oxygen-dependent preschooler have been accommodated at the same time as development of perceptual and cognitive skills have been encouraged through independent mobility. The criteria of weight, transportability and safety of the equipment were met. The involvement of the rehabilitation team and especially, Kevin's parents in the choice and design of the system contributed to its effectiveness.

ACKNOWLEDGEMENTS

Patti Howell, BScOT, Hugh MacMillan Medical Centre, Kevin's occupational therapist and coordinator of his mobility equipment. Assistive Devices Program, Ontario Ministry of Health and the Easter Seal Society for financial assistance to the parents to cover the equipment expense.

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CANADA

WEIGHT TRANSFER WHEELCHAIR SEAT - PATENT NO. 4,574,901

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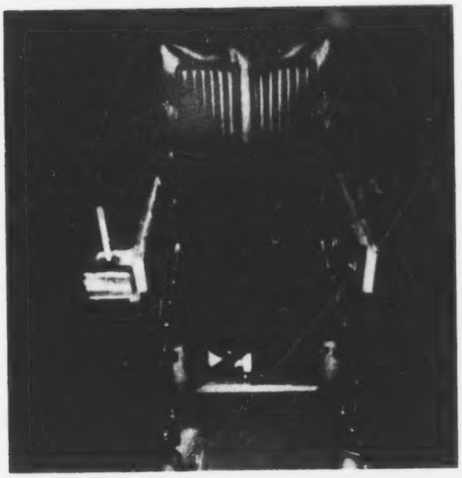


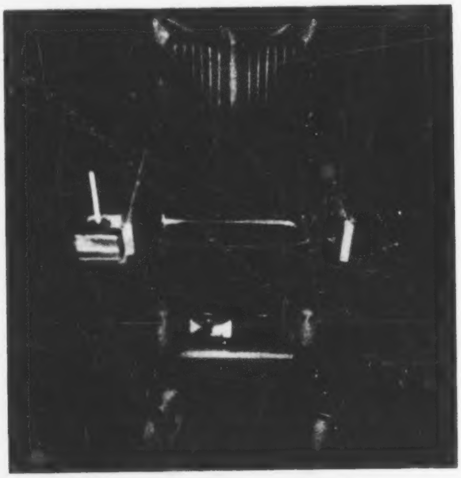
FULL SEAT

THIS WHEELCHAIR SEAT WAS DEVELOPED TO GIVE PRESSURE RELIEF TO THE BUTTOX AREA OF THE WHEELCHAIR USER THAT IS UNABLE TO SHIFT HIS/HIR OWN WEIGHT TO PREVENT PRESSURE SORES.

THIS SEAT HAS NEVER BEEN FIELD TESTED BUT THE CONCEPT IS BEING PRESENTED FOR EVALUATION AND HELP IN OBTAINING CLIENT TRIAL.

THE SEAT CAN BE USED WITH THE SOLID STATE TIMER DEVELOPED FOR THIS PURPOSE OR CAN BE OPERATED MANUALLY, EITHER BY CONTROLLING A 12V SWITCH OR A LEVER. THE PROTOTYPE OPERATES AUTOMATICALLY HOWEVER FOR DEMONSTRATION PURPOSES, WE DO USE THE ELECTRIC OVERRIDE SWITCH.

THIS SEAT CONCEPT CAN BE ADAPTED TO MANY CHAIRS ALREADY IN USE OR CAN BE INSTALLED DURING MANUFACTURE OF THE CHAIR.



BUTTOCK RELIEF POSITION

Ms GAIL PRICE, RN BS, SUBMITTED AN ARTICLE TO PARAPLEGIA NEWS IN THE SEPT. 1984 ISSUE THAT WAS DEVELOPED FROM A PRESENTATION GIVEN TO THE NATIONAL SERVICE OFFICER'S SEMINAR IN PORTLAND, OREGON IN MAY, 1984 BY DR. ELTORAI, ASSOCIATE CHIEF, SPINAL CORD INJURY SERVICE, LONG BEACH, CA VA MEDICAL CENTER. THIS ARTICLE INDICATED THERE ARE OVER A MILLION PEOPLE IN THIS COUNTRY WITH PRESSURE SORES. WE HAVE TO ASSUME MANY ARE CAUSED FROM PROLONGED SITTING IN ONE POSITION WITH OUT WEIGHT TRANSFER TO ALLOW BLOOD TO FLOW THRU THE AFFECTED AREA.

OUR GOAL IS TO OBTAIN FINANCE TO FIELD TEST THE UNIT OR PREFERABLY, WORK WITH AN EXISTING CHAIR MANUFACTURER TO FURTHER DEVELOP, MANUFACTURE AND MARKET THE SEAT.

A PROTOTYPE IS AVAILABLE AS INDICATED BY THE PICTURES.

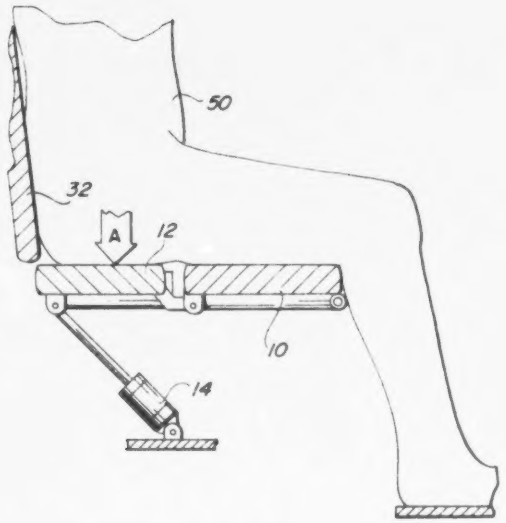

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FIG-4

Full SEAT

FIG 4 RELATES TO FULL SEAT ON PAGE ONE

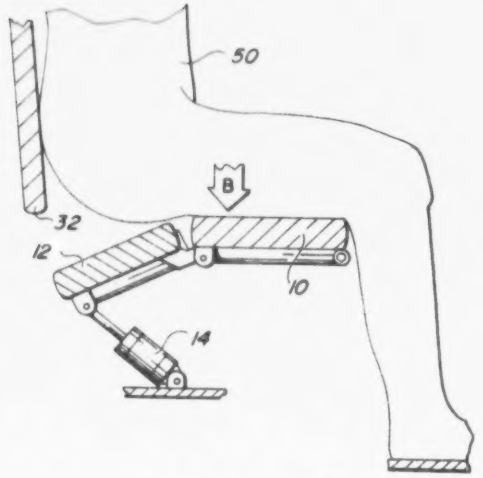
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FIG-5

Relief Position

FIG.5 RELATES TO BUTTOX RELIEF POSITION ON PAGE ONE.

RIDE COMFORT ANALYSIS OF WHEELCHAIRS

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University of Virginia Rehabilitation Engineering Center

INTRODUCTION:

Many wheelchair users are faced with a quandary when it comes to selecting a tire from the myriad of choices in today's marketplace. There is a great desire to use non-pneumatic tires such as those made of polyurethane for their long wear and low-maintenance, but this comes at the cost of higher rolling resistance and a harsher ride. The spring rates of solid tires are much higher than those of pneumatic tires, thus the solid tires are capable of absorbing only a fraction of the shock (such as a drop from a curb) absorbed by the pneumatic tire. One simple method of increasing shock absorption and thereby increasing ride comfort while using the long wear, low maintenance solid tires is by placing a spring shock absorption system on the wheelchair. This paper describes the design and analysis of such a system.

RIDE COMFORT:

Ride comfort is a highly subjective response that can nonetheless be quantified. There are numerous documents detailing methods for determining rider response to whole-body vibration, but there is no definitive "best" method. The works that have generated empirical comfort equations are not suitable for design use as their results are only applicable to the transportation system used in each particular study. Most works cite ISO 2631 "Guide for the evaluation of human exposure to whole-body vibration"(1) as a starting point for data acquisition and analysis. Many researchers have found the ISO analysis method deficient in comparison to their own methods, however, there is general agreement that the data acquisition method outlined therein should be used.

As described in ISO 2631, acceleration data is recorded for a frequency range of 1 - 80 Hz and is weighted according to the reduced comfort boundary limits. These limits define that the greatest human discomfort will be found in the range of 4 - 8 Hz for vertical accelerations and below 2 Hz for longitudinal accelerations. The acceleration data is measured by an accelerometer on the seat of the wheelchair. ISO 2631 requires the root mean square (rms) of the data to be calculated and then compared to the reduced comfort boundaries to see if the limits are violated.

Other documents describe different analysis methods for the acceleration data, and what appears to be the best way to analyze the data is to utilize several of these methods. If there is a consensus between two or more of the methods, then it can be assumed that the conclusion, whether that of comfort or discomfort, is correct. Some of the more important analysis methods are the Pradko-Lee absorbed power method(2) and the amplitude frequency distribution analysis method(3).

SUSPENSIONS AND DESIGN METHODOLOGY:

To utilize stiff, solid tires while maintaining an acceptable degree of ride comfort, some type of suspension must be utilized. With this use come many design decisions which are much like those made in the selection of an automobile suspension; design depends upon what the user desires. As with luxury automobiles, the use of low spring-rate springs (soft springs) and little damping gives a very smooth ride, but road feel and control are sacrificed. The use of stiffer springs yields a harsher ride, but better control, as is exhibited in sports cars. Although not as worrisome in automobiles, but still a concern, is the deflection (or bouncing) of the suspension under load. If the springs are overly soft, the wheelchair may bounce too much and the rider may not be able to maintain a good grip on the wheel rims. This problem of bouncing may also greatly influence the propulsion efficiency.

The goal of an optimal suspension design is to give a rider maximum comfort and maximum control, but since these two conditions are usually mutually exclusive, tradeoffs must be made. Much of the design must be based on the frame used, the weight of the rider, and the type of wheels and tires that are desired. The variables associated with these parts, along with the numerical values for the spring-rates and damping are basically easy to quantify and manipulate, however, those dealing with personal tastes as to a "soft" or "hard" ride are not. It is therefore the purpose of this design methodology to establish upper and lower limits for suspension selection so that the rider may have some input into this process. Given the above variables in the form of spring-rates and damping coefficients, a mathematical model of the wheelchair is created and is in turn analyzed for its overall ride characteristics. These results are then compared to an actual model for verification.

A MODEL SUSPENSION:

A simple linear spring damped suspension has been constructed and installed on an Invacare Rolls 500 STS wheelchair as shown in Figure 1. Each unit has twin upper support springs with damping provided through bronze bushings. Two 3/8 inch steel rods act as guides for the suspension's travel. The system is bolted onto the wheelchair so that the axle position, when a rider is in the wheelchair, will be the same as if the original support equipment had been in place. This axle position can be adjusted up or down with a set of large adjustment bolts. The added weight of the suspension system is approximately 11 pounds.

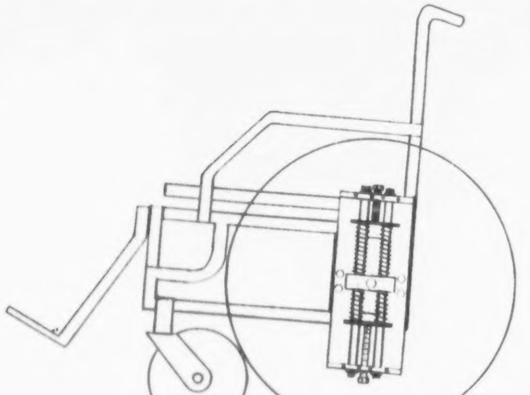

FIGURE 1 WHEELCHAIR WITH SUSPENSION

TESTING PROGRAM:

The wheelchair with 100 kg dummy is both towed on a treadmill over ISO 1/2 inch slats and dropped off a 5 inch curb. Accelerometers are mounted on the seat, just under the center of the dummy, to measure the acceleration spectrum. This data is recorded and analyzed as mentioned previously. Many different tire/wheel combinations were tested along with numerous different springs to determine each's influence on ride comfort. The testing program will also included a study of the variation in the angle of the support springs and sprung caster forks on comfort. To verify the results, human subjects were used in the same testing regimen.

Another benefit of the installation of a suspension is the increase in the life of the frame. It is expected that much of the force applied to the wheelchair will be absorbed by the suspension, thereby reducing the stress on the frame. To examine this phenomenon, strain gages were mounted on critical parts of the frame and the corresponding strain and stress histories are compared.

RESULTS AND DISCUSSION:

The research work as discussed is still in progress. Preliminary results comparing no suspension to use of 80 lb/in springs in the experimental suspension has demonstrated reductions of up to 50% in transmitted accelerations to the wheelchair at the crossbrace center.

It is hoped that this research will result in easily implemented design guidelines. By adding a spring-damper system to the wheelchair it is possible to utilize solid tires without sacrificing rider comfort. The wheelchair user will then be afforded the freedom from worry of flats and the constant maintenance associated with pneumatic tires.

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(3) Stikeleather, Larry F., "Review of Ride Vibration Standards and Tolerance Criteria," SAE 760413, 1976.

ACKNOWLEDGEMENTS:

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2 QUADRANT FEEDBACK PWM DC-DC CONVERTER FOR WHEELCHAIR MOTORS

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ABSTRACT

New designs for electric wheelchairs are aiming at longer life-span, better control response, higher efficiency with features for greater safety and convenience. These performance indices rely greatly on the controller. Application of feedback control in a converter helps to regulate the motor speed on different running surfaces and slopes. Energy storage converters have high sensitivity to parasitic effects that affect controller reliability. The newly developed dc-dc converter is a feedback pulse width modulater that drives wheelchair bidirectionally with good speed regulation and efficiency.

INTRODUCTION

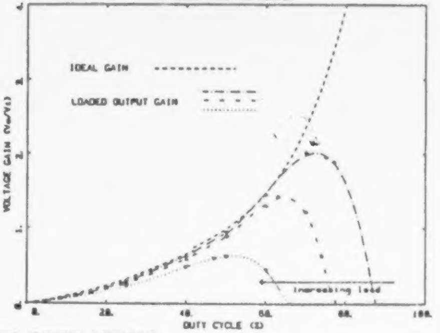
Design and improvement of electric wheelchairs has long been an important research topic in rehabilitation engineering. New designs are aiming at longer life-span, better control response, higher efficiency and other features to provide a safer and more convenient device for mobility.

Motor voltages deriving from joystick position are produced by dc-dc convertersin the speed controller. Commercially available controllers generally use PWM converters with a simple open loop proportional controller. Forward and backward rotation of the motor is achieved by mechanical relays, which are neither durable nor reliable. This kind of controller could not give desirable response since the output voltage is affected by the loading torque.

New converters using storage elements to give near dc output voltages have recently been developed. This converter design is quite promising in terms of conversion efficiency and current waveforms that favor motor and battery life [1]. Yet it has been observed that their efficiencies and output gain are very sensitive to parasitic effects [2]. It is also found that controller gain curve loses its monotonicity at high duty cycle and output current as shown in figure 1. Thus using this kind of converter in wheelchair controllers would require a more complicated circuitry to guarantee safety and reliability of system.

In this paper, a solid state two quadrant feedback PWM dc-dc converter is presented. A voltage proportional to the motor speed is fed back to the controller. Power MOSFETs are used for bidirectional controlling, and the circuit demonstrates a good output regulation and efficiency with varying load.

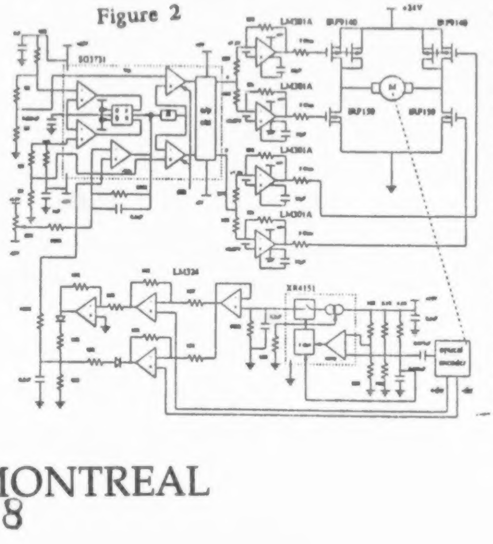
Figure 1 ACTUAL AND THEORETICAL VOLTAGE GAIN OF BOOST-BUCK CONVERTER



CIRCUIT OPERATION

A complete circuit diagram of the dc-dc converter is shown in figure 2. The main component used is an SG3731, which is a 2-quadrant PWM integrated circuit for a DC motor [3]. Its triangular-wave oscillator frequency is determined by a capacitor and the peak to peak voltage excursion between two comparators inputs. We have used a frequency of 23KHz in this case. The two outputs are normally at -5V and are switched to +5V when the triangular wave crosses above the upper threshold (to switch output A) or below the lower threshold (to switch output B). By adjusting the DC level of the triangular wave, the two output pulse widths are modulated. The DC control voltage is obtained from the output of the error amplifier, which adds the feedback voltage to the system input. Another feature of the IC is a safety operation pin INH, which is a digital shutdown terminal that forces the drivers of the IC to a floating high impedance state when driven low.

Figure 2



CIRCUIT DIAGRAM OF 2-QUADRANT FEEDBACK PWM DC-DC CONVERTER FOR MOTOR CONTROL

The limited output current of the IC cannot be used to drive the motor directly. To get high current drive capability, we used power MOSFETs as drivers. Op-amps are used to shift voltage levels for the FET gates. When one output of the IC is held at -5V, the gate voltage of the FETs will stay at levels so that the PFET is off and the NFET is on. When a modulated pulse of +5V is produced, the PFET is switched on and the NFET off for the same duration. Such arrangement enables the motor to be driven by maximum voltage close to 24V, while the transient current at switch off instant is carried to ground through the NFETs.

The main feature of this circuit is the presence of a feedback path. We used an optical encoder to sense the speed and direction, and an XR4151 to convert frequency to dc voltage. The op-amp circuit gives the feedback voltage an appropriate polarity.

CHOICE OF COMPONENTS

There are some restrictions on the use of several major components of this circuit.

The level shifting op-amps at the FET gates should have high enough slew rates to give replicates of the square wave output of SG3731. The LM301A has slew rate up to 10V/μs and it could be used at the chosen frequency. It does not include any internal capacitor and a 10pF was used for frequency compensation while maintaining a sufficient slew rate.

One of the IRF150 NFETs was used with a parallel pair of IRF9140 PFETs to drive the motor in one direction. The IRF150 has maximum drain current rating of 40A compared to 19A for the IRF9140. It was observed that if only a single IRF9140 was used, there was a rapid temperature increase.

An optical encoder is mounted at the shaft of each motor to sense the speed and direction. The model used is Datametric K15 series modular encoder. It produces two frequency signals with phase quadrature of 90 degrees so that the direction information can be extracted by a simple phase detecting circuit.

TEST RESULTS

The feedback converter was tested on voltage and speed regulation at varying load and efficiencies at constant torque. The results are compared with those of two commercially available models, namely the Invacare 400Hz and the Invacare New Zealand controllers.

Figure 3 shows the voltage and speed regulation at increasing torque loads. It can be observed that the feedback converter has a constant voltage output resulting in better speed regulation than either of the two commercial models. This feature provides smoother motion on inclined and rough surfaces.

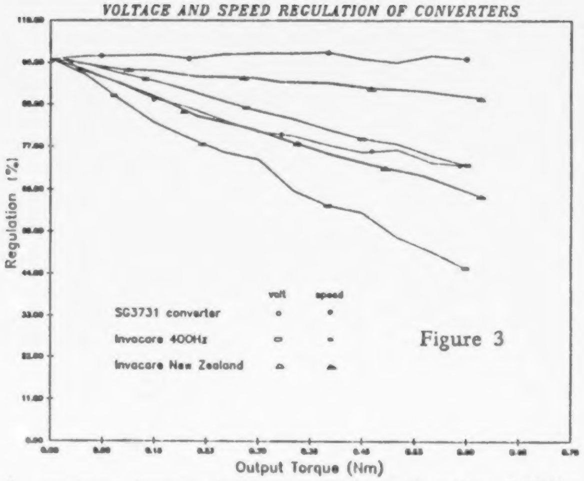


Figure 3

A constant torque test was performed using 0.27Nm (0.2 lb-ft) load. The result is shown in figure 4. The feedback converter has an efficiency very close to commercially available models, and it also has the widest range in output voltage for the three converters. Another significant advantage is the comparatively simpler circuit for the feedback controller, which uses only solid state devices and has a much lower component count than the other two.

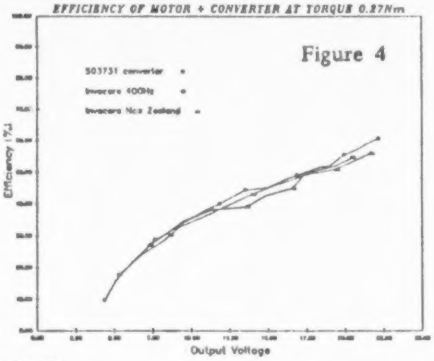


Figure 4

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UVa-REC, Charlottesville, Va22903, USA. NIDRR Grant #G00-83-00072

COMPRESSION STEP PLATES AS AN AID TO PROPER WHEELCHAIR POSITIONING

Jeffrey D. States, Kim M. Zimmerman, Dennis K. Tweedy

Design-Able, Inc. provides disabled persons with proper seating and positioning through the fabrication of custom equipment. In the course of our organization's work, the problem of extensor thrusting has frequently presented itself. We have developed compression step plates as a tool to help address this common positioning challenge.

Clients with increased extensor tone often push forward with their hips and down on the rigid step plates of a wheelchair. This is often seen with athetoid cerebral palsy clients, as well as during periods of excitement or agitation in spastic clients. The rigid foot plate provides proper weight bearing, but it also can create problems when a client exerts this downward extensor force. The resistance and leverage provided by the step plate serve as a basis for shifting the hips out of proper alignment and throwing the entire body into asymmetry.

At Design-Able, Inc., we have developed a device that absorbs much of the extensor thrusting responsible for many positioning problems. The device, known as a compression step plate, is composed of a variable thickness of polyurethane foam sandwiched between two ¼" ABS plastic panels. The thickness and density characteristics of the foam can be varied to meet the client's needs. We have found that foam with a load deflection index of 1844 seems suitable for most people.

The length dimension of the compression step plate is determined by the length of the client's foot, with shoe, plus 1½". The width is determined by the width of the wheelchair step plate to which the compression step plate is to be attached. The height dimension should be the difference between the calf measurement (behind the knee and heel) and the distance from the top of the seat edge to the wheelchair step plate. Adjustments to the step plate length or seat height may be necessary in order to achieve the proper clearance for compression. Calf length discrepancies can easily be accommodated by varying the thickness of the polyurethane foam.

Once the panels and foam are cut to size, they are fastened with a solvent-based contact cement. The units are then covered with coated nylon fabric and installed by inserting two 10-32 x 1¼" machine screws through each wheelchair step plate and into threaded inserts installed in the bottom panel of the compression pads. The top panel on the compression pad allows for the installation of a variety of commercially available shoe holders and straps.

Compression step plates have proven to be a functional, adaptable, and cost-effective method of addressing the problem of extensor thrusting. Especially when combined with an anti-thrust seat assembly and a molded seat belt, they are an excellent aid in attaining the goal of proper positioning.

AN INFLATION INDICATOR FOR USERS OF AIR-FILLED WHEELCHAIR CUSHIONS

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ABSTRACT

Air-filled cushions of various designs offer positive characteristics to many wheelchair users at risk for pressure sores. Although some models can be inflated for optimal pressure distribution in the clinic, no simple inexpensive tool is available to the client to monitor and maintain a corresponding internal air pressure. The device described in this paper was designed to achieve this goal.

BACKGROUND

Air-filled cushions offer a number of positive characteristics to the wheelchair user at risk for skin breakdown and are frequently prescribed for persons with spinal cord injury (1). Optimal seating interface pressure on these cushions is dependent on a low and narrow range (20-30 mm Hg) of inflation pressures when bearing body weight. This requires not only precise clinical evaluation and inflation adjustment during prescription but also reliable and accurate monitoring of proper inflation by the user (2). There is no simple, reliable and inexpensive indicator or gauge currently available to the users of air-filled cushions to allow clients independence in maintaining optimal pressure distribution. The device described in this paper was designed to meet this need. The air cushion used in this project was a standard Roho (St. Louis, IL) and the interface pressure evaluator was a hand-held Talley (International Medical Equipment, El Monte, CA) with a 100mm diameter transducer.

DESIGN CRITERIA

The gauge was designed to accurately and reliably indicate a prescribed optimal air pressure using components that could be operated and adjusted effectively by the both the clinician and the client. Other goals included low-cost, easy portability, repeatability and could be operated in the seated position without the need for postural adjustment.

DESIGN

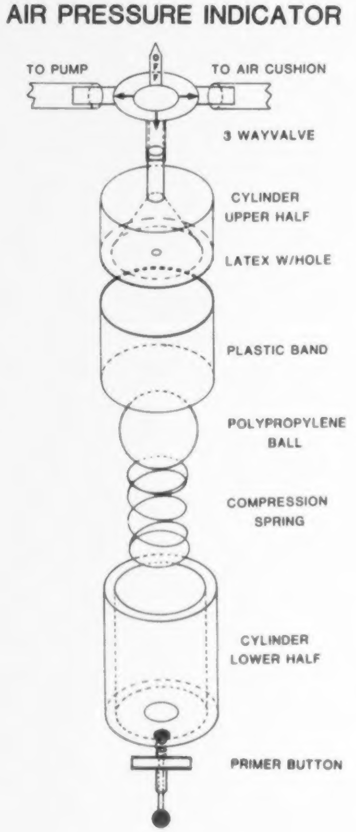

Figure 1 Exploded view of indicator

The device consists of two tubes which fit closely inside a plastic band. The upper tube is fitted with a air inlet attached to a plastic cone. A latex membrane is stretched across the base of the cone and sealed against the wall of the upper tube. The membrane is perforated by a small hole (3.0mm diam.) at the center. On the inside of the lower cylinder a spring with an attached polypropylene ball is glued to its base. The base is perforated allowing air to escape, but also loosely fitted with a primer button which compresses the spring and on release sets it in oscillation.

Air is pumped into the cushion via a three way valve allowing the cushion to be moderately overinflated. The valve is then adjusted to direct the air in the cushion to the inlet of the indicator. When the primer button is released the ball oscillates vigorously supported by the air-flow from the cushion in much the same way a pea whistle does. The conditions for oscillation are determined by the applied air pressure from the cushion the separation of the ball from the latex membrane and the elastic properties of the spring and membrane.

By adjustment of the lower cylinder the air pressure at which oscillation stops can be critically adjusted. The valve venting air from the cushion can then be closed establishing the required inflation pressure.

TEST RESULTS

The lower half of the cylinder was calibrated by measuring its insertion into the plastic band against a mercury manometer. Weights were placed on a board on top of an over-inflated Roho cushion. The cushion was repeatedly allowed to deflate to a selected internal pressure set at random by the indicator.

	Inflation pressure mm Hg n=3, mean, (s.d.) Applied Load lbs		
Insertion of cylinder ins	72	85	96
7/8	9 (.6)	8 (.6)	9 (.6)
1.0	17 (2)	17 (.6)	17 (.5)
1 1/8	20 (.6)	20 (1)	20 (0)
1 1/4	29 (4)	31 (2)	30 (2)
1 3/8	43 (3)	46 (3)	44 (5)

DISCUSSION

This device has demonstrated consistency in indicating inflation pressures approaching clinically acceptable values. Further optimization of indicator parameters (spring stiffness etc) will enable the device to be more consistent at higher pressures. Future goals include improvement of switches to activate the indicator and deactivate the air flow from the cushion. Field testing with spinal cord injured subjects will be undertaken to assess ease of operation and durability. Further minor modifications to the design may also offer the opportunity for the device to automatically cut off the air venting from the cushion at a prescribed pressure.

Although changes in body weight, build, bony prominence etc. will require ongoing vigilance, this tool can provide the user with immediate independence in optimal use of air-filled cushion systems.

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CLINICAL EVALUATION OF CUSTOM CONTOURED CUSHIONS ON SPINAL CORD INJURED SUBJECTS

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INTRODUCTION

Numerous wheelchair cushions have been designed to reduce tissue ischemia and provide body stability. Recently, the use of custom-molded systems have found increasing acceptance. "Foam-in-place" techniques are used to construct custom-molded systems to reduce pressure and provide body support. However, these methods can be costly since they require skilled labor for molding and fabrication.

Seat contours have been studied at UVA REC using a contour gage which is part of a system used to study body positioning, seat contour, and pressure distribution of spinal cord injured subjects [1]. In addition, an automated fabrication system has been designed to manufacture custom contoured cushions (CCC) [2].

Past research suggests that pressure distributions on contoured cushions are less than the distributions on flat foam [3]. External loading is the primary factor in tissue ischemia but there are other factors of significance. This study was designed to evaluate CCC's using both pressure data and other clinical variables.

METHODS

Four subjects with spinal cord lesions (C6-T10) were evaluated on their regular wheelchair cushion (2 Jay & 2 ROHO) and on a CCC.

Contour measurement was made by recording cushion deflection with 64 potentiometers arranged in a 16" X 16" (40x40 cm) array. Deformation data was sent to an LSI 11/23 computer where it was expanded from an 8 x 8 array to a 33 x 33 array using Whittaker's Reconstruction interpolation technique. The data was then transferred to a computerized milling machine for custom contouring.

An inexpensive 3" medium density high resilient foam (ILD= 45) which produced maximum deformations in the 1"-2" range was used for the CCCs.

Each subject chose to have a waterproof coating (RTV 732 silicon) applied to his/her cushion. After a preliminary pressure evaluation, the cushion was sent home with the subject for 3-5 days with a reminder to check his/her skin frequently.

Pressure measurements were made with the Oxford Pressure Monitor [4]. Twenty-four pressure points arranged in a 4 1/2"x 8 1/2" (11x22 cm) rectangle were recorded for analysis. This transducer was centrally placed in the region of the ischial tuberosities.

The four subjects were evaluated by a physical therapist to compare functional and postural effects of the CCC compared to the subjects current cushion. The following categories were evaluated by both observation and interveiw: transfer ability, skin reaction, propulsion, posture, spasticity, balance, pressure reliefs, and comfort.

RESULTS

The pressure data was arranged in a 2x24x4 Repeated Measures design for ANOVA. Comparision of the interaction of the cushion type (present vs. CCC) with the 24 pressure locations revealed the pressure distributions to be significantly ($p<0.05$) lower when the subjects were seated on the CCCs. The means and standard deviations of the pressure profiles are presented in Figure 1.

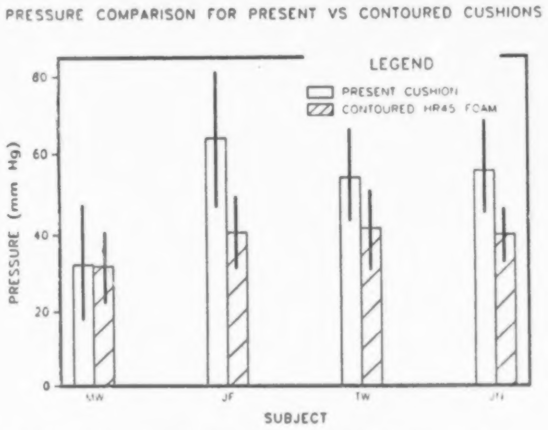

Fig. 1. Means and standard deviations for each regular cushion and CCC.

The results of the functional evaluation are summarized as follows:

Transfers: Functional abilities remained the same with the CCC for the three independent subjects. The dependent subject could not tell if she was seated properly in the contour of the cushion.

Balance: Two subjects felt their balance was the same as on their regular cushions and two felt their balance was better on the CCC.

Propulsion: Three subjects felt stable while propelling, while one felt slightly unsteady.

Comfort: Two subjects felt more comfortable on the CCC while two felt the same as on their present cushion. One subject reported a sense of "bottoming out" while decending a curb on the CCC.

Spasticity: All four subjects displayed varying degrees of LE spasticity, however, none reported any increase while using the CCC.

Posture: Trunk symmetry, pelvic rotation, obliquity, and A-P tilt, and overall appearance were considered. Two subjects maintained good posture similar to their normal cushion. The other two displayed improved posture, showing less asymmetry and improved pelvic position. One subject felt significantly more erect.

Skin Reactions: Subjects reported on self-skin examinations and none mentioned redness or skin irritations after using the CCC.

Pressure Reliefs & Positioning: All four subjects used push ups, side leans, or weight shifts. Three could reposition easily into the contour site , but the fourth had difficulty locating the proper position. However, it was observed that subjects could not simply move about on the CCC as they do on their regular cushion since only one specific location is provided by the contour.

DISCUSSION

The results of the pressure analysis look very promising, even with a small number of subjects. The mean pressures were lowered as well as the dispersion of pressure values, signaling a more uniform distribution. Contouring increases the contact area before deformation of the cushion and buttocks which allows lower interface pressures and reduced peak pressures. Uniform pressures imply lessened pressure gradients which contribute to shear forces on tissue. Therefore, the data seems to indicate that contoured cushions improve the buttock-cushion interface by lowering the normal force and reducing the potential for shear forces on the tissue.

In the functional evaluation, the responses from these four subjects were favorable towards the CCC. Functional abilities, balance, postural alignment, and comfort were often enhanced. The main concern was that the subject had to sit exactly into the contour site, similar to a "lock and key" fit. This limits the subjects spontaneous mobility on the cushion. Loss of sensation and level of paralysis influences the users ability to know when they are in the correct position, and must be considered when using the CCC.

Even though pressure considerations may be overused and overrated, the results of the clinical aspects indicate that custom contouring warrants continued research and clinical testing. Several variables need further study including use of different types of cushions with differing density and stiffness, determining the lifespan of contoured foam, and identifying the effect of the depth of contour on comfort, proper positioning, and pressure characteristics.

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FAUTEUIL ROULANT PERSONNALISE POUR BLESSES MEDULLAIRES ADAPTE A LA COURSE DE SEMI-FOND ET FOND

LE CLAIRE G., GEZEQUEL B., MAHE A., DUVAL J.C., BOULANGER Y.L.

Le développement important des courses de Marathon, en fauteuil roulant en FRANCE et en EUROPE, nous a amené en tant qu'équipe de Rééducation a réfléchir sur la conception et la réalisation d'un matériel adapté, personnalisé, de cout modéré, au performances optimales.

Les caracteristiques mécaniques utiles pour ce type d'activités sportives découlent pour une grande part de l'étude du geste sportif ; le cycle de propulsion se décompose en deux périodes : une phase initiale descendante pendant laquelle l'extrémité du membre supérieur aborde la main courante, puis le mouvement s'accélèrant vient la frapper avec un maximum de frottements ; à laquelle succède une phase ascendante, la main décrivant un demi-cercle du bas vers le haut. Pendant ce cycle, l'épaule reste en rétropulsion et doit se situer dans le plan vertical issu de la main courante à l'aplomb de son bord antérieur et autorise l'accompagnement du cercle de propulsion jusqu'à sa partie la plus basse. Ceci impose une fixité de l'ensemble du tronc, qui placé en antéflexion, trouve sa stabilité latérale et antérieure respectivement sur des protège-troncs adaptés étroitement à la morphologie du sportif, et indirectement sur un repose-pied, dont la position conditionne l'obliguité du tronc par rapport à la face antérieure des membres inférieurs placés en triple flexion.

La conséquence de ces concepts permet de distinguer deux parties très différentes, s'opposant dans leur réalisation :

- l'arrière du fauteuil, hautement personnalisé,
- l'avant standardisé,
- les autres impératifs étant la rigidité de l'ensemble, la stabilité au sol et le faible poids.

L'arrière du fauteuil roulant, élément de propulsion et d'assise, trouve ses originalités dans sa réalisation sur mesure, et l'adjonction d'aides à la stabilisation :

Le chassis se décompose en une chape avec palier de roue, placé tous les deux centimètres, doublement rigidifié par trois barres de liaison et de parallélisme dans le plan horizontal, et deux montants latéraux dans le plan vertical reliés par une plaque métallique rectangulaire. Les protège-troncs, de même cintrage que la jante, placés à cinq millimètres du boyau, viennent se mouler sur le thorax antéro-latéral. Le siège, en toile plastifiée est de profondeur fixe (200 mm), sa largeur représente la distance trochanter-trochanter, plus dix millimètres. Les roues arrières rayonnées en parapluie, munies de boyaux, s'angulent à 7° sur la chape, leur diamètre se situant à 600, 650, voire 700 mm, selon la morphologie du sportif. Les mains courantes, de section croissante (12 à 25 mm) en fonction de l'intégrité motrice totale ou partielle des membres supérieurs, équipées de composants anti-dérapants à base de boyau recouvert de résine, se situent dans un plan parallèle aux roues arrières, la puissance de l'athlète déterminant le rapport de développement dont découle le diamètre des mains courantes, variant de 290 à 375 mm.

Le train avant, élément standardisé, se décompose en un cadre rectangulaire large, rigidifié et relié par l'intermédiaire de douilles directionnelles aux roues placées dans un plan strictement vertical. La nécessité absolue d'un parallélisme parfait impose un jumelage précis assurée par une barre de liaison filtrée stabilisatrice, complétée d'un correcteur de devers. Les roues avant équipées de boyaux ont un diamètre fixé à 350 mm, ce qui permet un meilleur roulement et l'absorption des irrégularités du revêtement de sol. La guidance repose sur deux poignées directionnelles placées à la perpendiculaire des roues. Le repose pied, élément indirect de stabilité thoracique se situe dans le plan horizontal de projection des bords antérieurs de la main courante et roue arrière. Sa hauteur est fonction de la gravité du handicap neurologique qui impose, pour le tétraplégique incomplet, l'appui du tronc sur les segments fémoraux.

Chassis avant et arrière sont solidarisés par des barres de liaison placées en triangulation assurant la solidité et la rigidité, le poids de l'ensemble, grâce à l'utilisation de tubes d'acier, se situant au dessous des 10 kgs.

La stabilité au sol relève de deux paramètres la largeur suffisante du cadre avant, le carrossage à 7° des roues arrières.

L'étude comparative des fauteuils roulants "sport" commercialisés en EUROPE, montre que l'ensemble des caractéristiques mécaniques utiles à la course de semi-fond et fond, ne sont jamais totalement réunies, les différences essentielles résidant sur la personnalisation de l'assise arrière, le carrossage, l'adaptation des mains courantes, le diamètre des roues avant, l'équipement par poignées directionnelles, stabilisateur, système anti-devers et repose-pieds.

Le fauteuil prototype que nous proposons trouve son originalité dans sa conception sur mesure, l'utilisation de matériaux plus sophistiqués (alliages spéciaux, titane) constitue un des objectifs actuels.

Ainsi pensons nous avoir apporté aujourd'hui, des solutions techniques et pratiques à ces nouveaux Athlètes dont les performances sportives n'ont pas fini de nous étonner.

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ASPECTS CLINIQUES ET TECHNOLOGIQUES DANS LE CHOIX OPTIMAL D'UN FAUTEUIL ROULANT

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INTRODUCTION

Le fauteuil roulant a bénéficié depuis le début du siècle d'une évolution marquée. En Amérique du Nord, il semble que les premières chaises en bois sont apparues durant la guerre de Sécession. Cet appareil ne connait que des raffinements mineurs jusqu'au moment où, en 1932, Herbert A. Everest et Harry C. Jennings fabriquèrent une chaise fiable en métal. Ce modèle est à l'origine de l'explosion de la gamme de fauteuils roulants actuels parmi lesquels on retrouve: le fauteuil à propulsion électrique, le fauteuil léger et ultra-léger, le fauteuil destiné aux sports, le fauteuil permettant la verticalisation, etc...

La fraction de la population qui utilise un fauteuil roulant ne cesse de s'accroître. En effet, l'ouverture sociale, l'augmentation de l'espérance de vie et la diminution des décès suite à une maladie ou à un traumatisme, favorisent l'emploi de l'appareil.

Plusieurs usagers passent une grande partie de la journée dans leur fauteuil, celui-ci devenant, par le fait même, un espace primaire qui tend à se confondre avec l'espace personnel, parfois au point de devenir un "prolongement" de leur corps. Il est par conséquent essentiel que dans l'attribution du fauteuil roulant, on concilie les besoins du client avec les limites inhérentes à l'appareil et les contraintes externes (coût, règles d'attribution des organismes payeurs, disponibilités...)

Tout au long du processus d'attribution d'un fauteuil roulant, on recherchera à maximiser les qualités de l'appareil choisi, pour répondre aux critères suivant: autonomie dans les déplacements et les transferts, confort, sécurité, respect de l'anthropométrie, accès à l'environnement, esthétique, légèreté, solidité, durabilité, coût, adaptabilité des composants.

FONCTIONNEMENT DE LA CLINIQUE DE FAUTEUIL ROULANT

Le but de la clinique est d'évaluer les clients le plus globalement possible. Par la suite nous fournissons le fauteuil roulant qui répondra le mieux à ses besoins médicaux et environnementaux.

L'équipe se compose du médecin prescripteur, de l'ergothérapeute, du technicien et du patient. Le médecin confirme le diagnostic du patient ainsi que les indications et contre-indications reliées à la prescription du fauteuil roulant.

L'ergothérapeute analyse les besoins du client en terme de déplacements et d'activités fonctionnelles. Le technicien quant à lui, peut être appelé à se prononcer sur la construction ou la faisabilité des appareils. Il intervient également au niveau de la simulation ou mise en situation du patient pratiquée par l'équipe.

Le client lui-même intervient à toutes les étapes pour exprimer ses propres besoins et informer l'équipe sur son vécu au moment des essais ou simulations.

Nous distingons les étapes suivantes dans notre démarche:

1. Evaluation clinique
2. Etude des données, priorisation des besoins et recommandations initiales
3. Simulation, mise en situation et recommandation finale
4. Ajustements et livraison
5. Contrôle

1. L'évaluation clinique se compose du diagnostic médical, du bilan fonctionnel, des mesures anthropométriques, du bilan des activités quotidiennes et du bilan socio-professionnel.

Le diagnostic et les conditions associés sont la base de toute évaluation. En effet, cette première étape orientera nos choix ultérieurs compte tenu du caractère évolutif ou non des pathologies. De plus, les règles d'attribution des organismes payeurs sont établies, entre autres, en fonction du diagnostic.

Le bilan fonctionnel nous trace un tableau objectif des capacités résiduelles physiques et mentales du client. Cela comprend l'évaluation de l'amplitude des mouvements, de la force musculaire, de la coordination ainsi que l'appréciation des capacités sensorielles telles que la vision, l'audition et la sensibilité superficielle et profonde. On doit également tenir compte de la capacité intellectuelle à exécuter des mouvements ou à effectuer des tâches, telle la conduite d'un fauteuil roulant. Bref, le bilan fonctionnel est l'analyse des moyens dont dispose l'individu pour intervenir sur son appareil..

Les mesures anthropométriques nous permettent de personnaliser le fauteuil roulant du point de vue de ses dimensions intérieures. L'appréciation de chaque segment du coprs: jambe, cuisse, hanche, tronc, bras détermine la dimension correspondante des appui-jambes, sièges, dossiers et accoudoirs dans la construction du fauteuil.

Le bilan des activités quotidiennes nous précise les besoins spécifiques du client dans l'accomplissement de tâches telles l'hygiène, les transferts, l'alimentation, l'habillage... Ces besoins déterminent directement le choix des accessoires et des composants du fauteuil roulant.

Le bilan socio-professionnel nous indique dans quel environnement et pour quelles activités, le fauteuil sera utilisé. Il nous informe également sur les contraintes d'accessibilité qui influenceront le choix des mesures extérieures du fauteuil roulant. De plus, certaines activités privilégiées par le client nous obligent à tenir compte de la résistance des matériaux utilisés dans la construction du fauteuil ainsi que de ses spécifications mécaniques.

2. L'étude des données fait suite à l'évaluation clinique et donne lieu à une priorisation des besoins de l'individu. La priorité peut aller au travail, aux activités sportives, au confort ou à un positionnement thérapeutique quelconque.

Cette priorisation s'établit d'une façon objective à partir de tous les éléments répertoriés à l'évaluation clinique ainsi que de contraintes externes telles: le financement, l'esthétique, la disponibilité etc. Un choix initial se dégage alors de cette analyse multidisciplinaire.

Les personnes handicapées disposent rarement de plus d'un fauteuil pour toutes leurs activités.

Voilà pourquoi une combinaison de plusieurs besoins, parfois contradictoires s'impose. Ainsi le plus grand confort peut s'opposer à la légèreté ou la facilité de propulsion; le positionnement optimal peut interférer avec l'autonomie dans les activités etc.

Le tableau I illustre les catégories possibles de fauteuils roulants pouvant répondre aux besoins du client.

Tableau 1

Type de F.R.	Siège standard	Type de positionnement		
		Modulaire	Moulé	Mixte
Base Motorisée	▨	▨	▨	▨
F.R. Standard	▨	▨	▨	▨
F.R. sur mesures	▨	▨	▨	▨
F.R. ultra léger	▨	▨		
F.R. sport	▨			

3.La simulation consiste à fournir au client un appareillage se rapprochant le plus possible de celui recommandé. Cette étape consiste à vérifier la pertinence de la recommandation et à apporter les modifications qui s'imposent: le client étant alors confronté pour la première fois avec l'appareil. Le fauteuil roulant ainsi adapté pourra si nécessaire, faire l'objet d'une mise en situation.

La mise en situation permet à l'usager d'être confronté à des activités réelles ou similaires à celles qu'il rencontrera régulièrement. Ceci peut se faire au Centre Francois-Charon (activités similaires) ou au besoin au domicile, au travail, etc... (activités réelles).

A partir des éléments recueillis lors de la mise en situation, l'équipe élabore la recommandation finale.

Toute évaluation n'est pas et ne doit pas être statique cependant. En effet il existe une intéraction perpétuelle entre le client ses caractéristiques (bio-psycho-sociales), ses besoins (mobilité, confort, etc) et le matériel disponible. Par exemple les besoins en terme de mobilité peuvent changer en fonction d'une évolution de la pathologie ce qui nécessitera des changements au niveau du fauteuil roulant ou de ses accessoires. Inversement, un appareillage adéquat fait améliorer la condition physique du client, ce qui pourait très bien entraîner la création de nouveaux besoins et donc éventuellement la nécessité d'un nouvel équipement.

4./5. C'est pourquoi des contrôles réguliers suivant les ajustements et la livraison finale, sont nécessaires afin de s'assurer que l'adéquation entre l'usager et son fauteuil roulant est optimale.

CONCLUSION

Il peut sembler curieux que le fauteuil le plus largement commercialisé n'a que fort peu évolué depuis cinquante ans. La configuration résultait de sa simplicité et de son faible coût de construction. La large part que ce type d'appareil occupe encore aujourd'hui sur le marché a de quoi nous désoler. Les restrictions financières mises de l'avant par les organismes payeurs ne sont pas étrangères à cette situation.

Malgré cette résistance du milieu, les personnes handicapées, par leur intégration sociale de plus en plus actives, forcent le développement et l'amélioration d'appareillages adaptés à toutes sortes d'activité. Citons le sport, le travail, etc.

L'homme ne peut intéragir efficacement avec l'environnement que s'il dispose de mobilité. Cependant cette mobilité doit tendre vers l'autonomie. Le fauteuil roulant se doit de s'effacer le plus possible, c'est à dire devenir le prolongement du corps à l'instar d'une prothèse.

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WHEELED WALKER FOR HANDICAPPED CHILDREN

CATHERINE MARIE SOROCZAN, STEPHEN QUESNELLE, LEONE PLOEG

INTRODUCTION

In Canada today there are approximately 50,000 children who, due to various disabilities, are unable to walk. To them walking is not innate but a learned process, accomplished only through time with the help of walking aids and expert physiotherapy. This process increases in difficulty when working with a child who is mentally handicapped since they are often unaware of their surroundings and have extremely limited body control. Proper equipment in the form of; wheeled walkers, braces, and crutches are extremely beneficial in aiding the handicapped child in general but may not be adequately tailored to the individual child's needs, especially those whose handicaps extend to cognitive disabilities.

METHODS

A meeting was held with the special education teaching staff at Thomas D'Arcy McGee elementary school. The staff defined the criteria for a walker for a student with cerebral palsy who has little body control and suffers from periodic seizures.

The major problem seemed to be a lack of adequate upper body support in the walker being used. The child, Lucas, was supported with the help of pillows and could still move his body around to a large extent. A better support system is required to keep the child in an upright position so that he can concentrate solely on the task of moving his legs.

The frame of the walker is required to be extremely stable, capable of holding a child's full body weight in the event that he suffers a seizure in the unit and becomes dependent upon it for support. The walker must not tip easily in any direction and offer adequate leg room to prevent the child's legs from becoming entangled in the frame, this being of special importance for children who cannot rectify the situation on their own.

The final requirement is an element of adjustability inherent in the frame to accommodate different children and the growing child.

RESULTS

Following the specific criteria set out a prototype of the wheeled walker has been designed and built concentrating on the stability, upper body support, and adjustability factors.

This unit is fabricated from a lightweight PVC plastic which is durable and easy to work with. The piping can be cut to size with a simple hacksaw while the ready made T and elbow joints allow for easy assembly of the frame. Overall the piping gives the walker a warm, modern, aesthetically pleasing look as compared to the metallic walkers on the market.

The design features a unique 6-sided frame which enhances its stability. The wide base allows the child ample leg room while the upper unit keeps the child well within the walker's centre of gravity, thus making it virtually impossible to tip over even in the event of a seizure.

The upper section features an adjustable support unit composed of a vinyl chest pad and back brace. This feature frees the child to concentrate solely on the task of walking while snugly holding the body in an upright position.

The moveable back brace allows for different sized children to use it.

At present the upper vertical pipes can be removed for easy assembly/ disassembly. These pipes can be substituted for larger or smaller pipes to accommodate the size of the user. As well the seat is held on with adjustable seat belt type straps so that it can be raised or lowered as necessary or even removed as determined by the child's progress.

DISCUSSION

The support walker prototype was field tested at Thomas D'Arcy McGee school with Lucas for a period of 2 weeks under the supervision of his teacher, Earl Donovan and physiotherapist, Janet Leish. A follow up evaluation confirmed that upon use the walker did not tip even when Lucas suffered a seizure in it. Both the school and Lucas's mother are anxious to retain the walker on a permanent basis pending legalities on liability. Mr. Donovan believes that use of the walker can be extended to any child requiring some sort of upper body support for mobility.

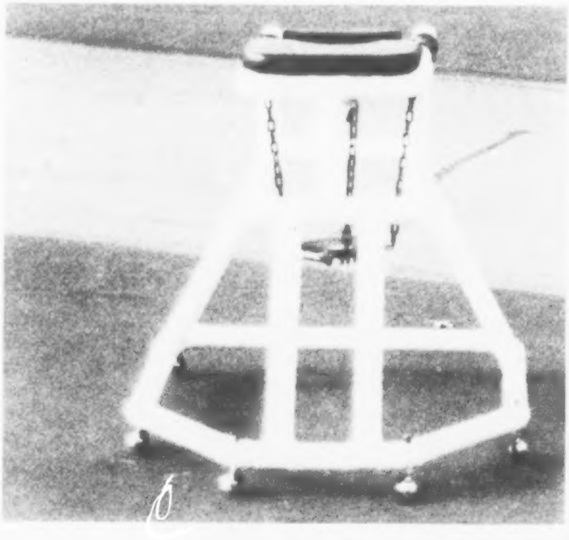
Looking ahead, the design team hopes to produce a model, W.4. made of composite fibers which will increase the strength of the frame but not add to its weight. As well the team intends to incorporate a removable tray like structure on the front to allow for a child to eat or play with objects while in a standing/ sitting position. This multipurpose feature will allow the physiotherapist to keep the child in one unit instead of carrying the child from a wheelchair to a walker between lunches and sessions.

CONCLUSIONS

The wheeled walker design offers a unique frame geometry and increased upper body support to aid children with limited body control. Though originally designed to tailor to the specific needs of Lucas this walker addresses the requirements of a general category of handicapped children who require upper body support within a solid stable frame unit.

ACKNOWLEDGEMENTS

The design team would like to thank Earl Donovan, Janet Leish, Sherri Thompson, Mrs. Donlan, and Lucas of Thomas D'Arcy McGee school for their contribution in the designing and field testing of the walker. We would also like to thank Mr. Paul Scorrill and Mr. Hogan for donating the necessary materials for the prototype. Finally we would like to thank Mr. Don Raizenne and Mr. Robin Black of the National Research Council for their advice.



BETTER WHEELCHAIRS, LOWER COSTS.

R.J. DEN ADEL

INTRODUCTION.

De Gemeenschappelijke Medische Dienst (GMD, Joint Medical Service) has an advising task within the Social Insurance Acts in the Netherlands. One of the areas in which the GMD is involved is the prescription of technical aids. The staffdepartments carry out evaluations and formulate requirements for tecchnical aids. A main project in which the quality of wheelchairs is evaluated and connected to the prescription policy was started in 1985 and has given promising results so far.
About 55% of all provided wheelchairs is payed through the GMD (users obtain the loan of the wheelchairs).

The aims of the project are:
- increasing the (functional and technical) quality of wheelchairs
- facilitation of selection procedure for the individual
- improve cost-control
- facilitation and increase possibility of re-issue.

METHODS

The whole area of wheelchair-users is divided into 52 targetgroups.
A targetgroup in defined as a group of wheelchair users with the same impairments, disabilities and using behaviour, related to properties of wheelchairs. (For the description of a wheelchairtype for a certiain targetgroup, see "The Biposture Wheelchair" by mr. H.A.M. Staarink).
Requirements are related to the specific needs of each targetgroup.
The evaluation is devided into three main steps:
- the entry check, the basic requirements like minimal parking brake function, positive seating angle, etc., if the chair passes the entry check it will be admitted for prescription and enters the next step:
- the funcional, technical and economical evaluation.
  A complex relation of quite a lot of requirements is described for each targetgroup by using a certain system of scoring and weighing of scores, giving a general idea of the wheelchair meeting the needs of the targetgroup. The result is a ranking of wheelchairs within each targetgroup (in order of increasing quality).
- the quality-cost ratio and selection of the "cheapest adequate wheelchair".
  For each targetgroup the quality ranking is compared to the cost ranking. In this comparison an optimal quality-cost-ratio is choosen related to the needs of the targetgroup and to the aims of the project.
  For each targetgroup this will result into a wheelchair which will be prescribed with preference. If this prefered chair is not adequate to the individual user the prescriber can choose one of the other

wheelchairs, which has passed the entry check.

RESULTS

The project was started in 1985 by discribing the targetgroups and the connected requirements.
A first evaluation was carried out, based on existing productinformation, extended with additional measurements. A first "package of adequate wheelchairs" was published in 1986.
In 1987 almost all wheelchairs (for adults) available on the Dutch market were tested again. This time iit were new chairs, more adapted to the published requirements. The second package, hand-propelled wheelchairs, was published in June "87 and electrically powered wheelchairs in February 1988). At the moment the testing and evaluation of the third package of handpropelled wheelchair is being carried out including ISO-tests for strength, corrosion and durability.
During the last three years we achieved:

- a more flexible market structure, used to requirements and changes in requirements and prescription policy
- an increase of quality of wheel chairs (so far mainly on functional aspects)
- a strong activity on innovation, new concepts showing up
- a decrease of costs, so far mainly due to lower prices and lower garantees
- a possibility to evaluate the prescribing behaviour of the advisers in order to achieve equal prescription throughout the country.

DISCUSSION.

The unique position of the GMD in the Netherlands enables us to achieve positive results on the discribed aims.
To get as much effect as possible we have organised a discussion platform in which users and advisers are participating. In this group experiences of users, advisers, prescribers are brought together and transformed into new requirements for wheelchairs (always related to targetgroups).
The GMD has the final responsibility for the choice of the requirements which are used for the testing procedure for the next package of wheelchairs.
However we had a lot of discussions in the first two years about the system, the requirements and the introduction, e have now reached the point that positive results can be seen and the system is accepted in general.

CONCLUSION.

The project has shown that a connection between requirements, evaluation results on quality and a quality-cost consideration on one hand and a prescription policy on the other hand is very effective for increasing wheelchair quality and reducing Over all costs. A flexible market structure is a spin off effect. As we are quite satisfied about the results we will stimulate
EC countries to join this approach.
We will continue our work on wheelchairs in ISO and maybe in the future it will be possible to cooperate on mondial scale.

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THE BIPOSTURE WHEELCHAIR.

H.A.M. STAARINK

In the Netherlands the Gemeenschappelijke Medische Dienst (Joint Medical Service) is responsible for the issueing of wheelchairs. The GMD covers almost 55% of the market.

In order to improve the quality of wheelchairs a project has been started to analyse the functional needs. The result is a description of 52 wheelchairtypes, needed to cover the needs of about 90% of the wheelchair users. Every wheelchairtype corresponds with a defined targetgroup. (See "Better Wheelchairs, Lower Costs, by mr. R.J. den Adel.)

These 52 types are build up of main features concerning propulsion, area of use, sitting posture and foldability.

We spent much effort to analyse and establish sitting posture features. Activities in the wheelchair, handicap, duration of use and the way of alternating the sitting posture are the ingredients for these analysis.

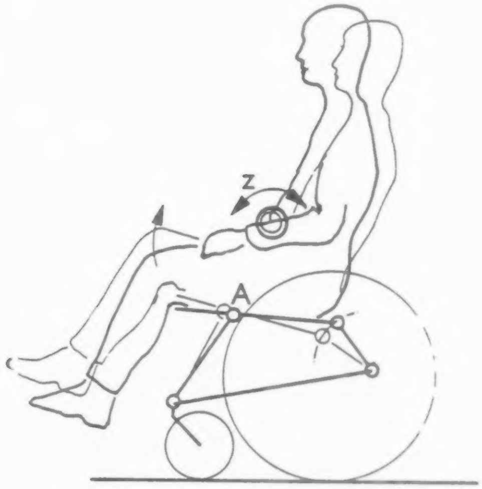
Important angles of the sitting posture are: the one between seat and backrest - angle alpha - and the position of the sitting posture as a whole expressed in the angle between seat and horizontal - angle phi.

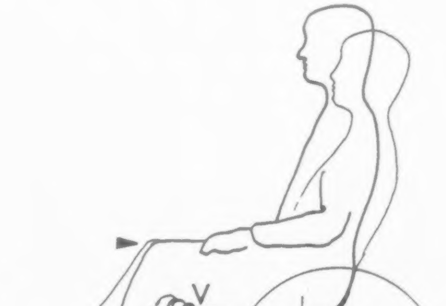
Further it is important to know who is going to alternate the sitting posture the user or his attendant. Getting in and out of a wheelchair, watching TV, working and relaxed sitting need different postures.

We established that all-day wheelchair use needs the posibility of at least 2 sitting postures: one for getting easily in and out of the chair and one for relaxed sitting. In the first position muscle activities are neccessary to maintain the posture, for the second position it is not.

We develloped standards for a hand propelled wheelchair which enables those sitting postures, we named it the biposture wheelchair.

This is the most simple wheelchair for all-day (to our opinion).





The biposture wheelchair has the following specifications:

angle phi 1 = 0° - 10° adjustable at delivery
angle alpha 1 = 95° - 110° adjustable at delivery
angle phi 2 = phi 1 + 10° adjustable by user
angle alpha 2 = angle alpha 1

Because there was no biposture wheelchair available on the market we have spread reports to stimulate manufacturers to design and supply such wheelchairs. That was started in 1985. In January 1988 only one biposture (electrically powered) wheelchair was offered. In order to stimulate the design of a biposture hand propelled wheelchair we started a so called demonstration project.
The alternating of the position of the knees, head and centre of gravity are important comparing points between the solutions.
It should be possible to stay at a table during altering the posture.
It is also important that the stability doesnot increase or deminish too much.
Big movements of knees an head should be prevented.
We made a model of the most promising concept. In order to investigate the ease of use and the influence of pivot point position we build in some posibilities to do so.
Reports of the project are sent to manufacturers.
Employees of the GMD have been stimulated to issue the biposture wheelchair for all-day use.

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SEATING & WHEELED MOBILITY FOR SEVERELY DISABLED CHILDREN IN NEW ZEALAND

Iles, Geoffrey

The New Zealand Disabilities Resource Centre

INTRODUCTION

The Disabilities Resource Centre is a national Centre which assists disabled people by providing them with products and services which facilitate their wellbeing.

This paper briefly describes the range of seating and mobility equipment developed by the Centre for children. The examples chosen here cover a variety of severe disabilities:

* amelia
* osteogenesis imperfecta
* cerebral palsy

All of these devices except for the last represent adaptations to the SEDO wheelchair, a modular general purpose wheelchair for children aged between 5 and 12 years. The SEDO wheelchair has manual, self propelled and powered derivatives and was developed by the Centre in the early 1980's (1). Its modular design facilitates the type of adaptations illustrated here. Lastly the Centre has developed a small powered wheelchair or 'Go Cart' for the younger cerebral palsied child.

METHODS

A Height Adjustable Chair for Amelic children

Amelic children manipulate their environment using a remnant limb (where available), mouth, chin and/or shoulder.

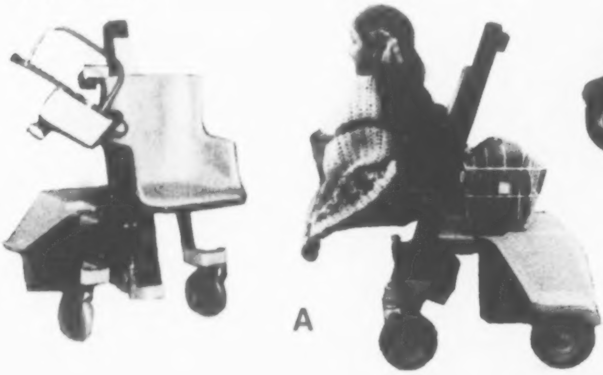
The wheelchair depicted in figures 'A' facilitates activities of daily living by enabling these children to accurately position themselves relative to the task at hand using their joystick and the height adjustment capability of the wheelchair. The chair carries the child much like a forklift truck carries its load. The weight of batteries, motors and controller is used to counter-balance the weight of the child providing the child with an excellent forward position for reaching the environment. The use of height adjustability in this manner was inspired by Booth (2).

A useful additional feature of the chair is a safety arm which pivots upward out of the way when not needed or when transferring. This arm is often used to carry the joystick and other controls for manipulation by the chin and shoulder. It is powered by an additional small electric motor activated by a shoulder switch. A complete description of this wheelchair and arm can be found in an earlier paper by the author (3).

A Standup Wheelchair for Children with Osteogenesis Imperfecta

The above wheelchair has been further refined for a child with osteogenesis imperfecta to enable him to partially stand taking weight on his legs. Weight bearing is considered important in order to stimulate the more normal development of such children's legs reducing the risk of osteoporosis.

Motloch (4) in association with the Stanford Children's Hospital developed a powered standing/sitting frame for a similar child from Australia.



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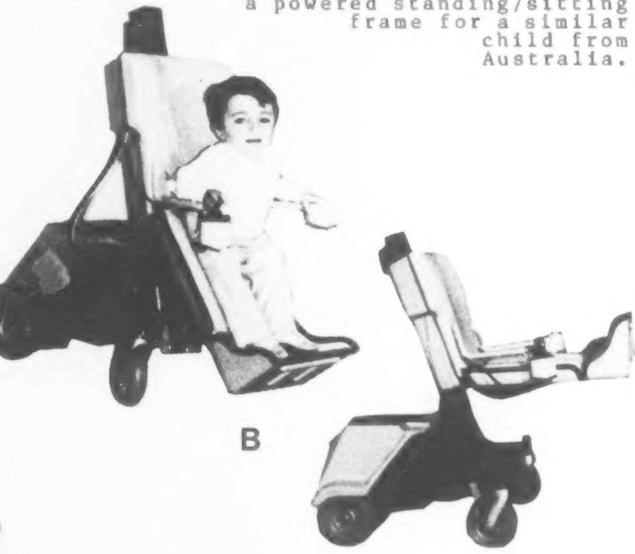

B

This concept was incorporated into the height adjustable chair resulting in the chair depicted in figures 'B' below. The most troublesome aspect of the design was the armrests whose height relative to the seat must change with the degree of standing/sitting. The armrests also needed to pivot horizontally so they could be swung out of the way when necessary.

As with the first wheelchair, height adjustability gives the child much greater access to his environment and permits a limited degree of independent transfer to such surfaces as his own bed. A more detailed description of this work has been written by the author (5).

Powered Mobility for Cerebral Palsied Children

Figure'C' shows the Centre's SEDO wheelchair adapted for the cerebral palsied child. Important features of the chair include:

- * provision of 30 and 35 cm wide seat shells that facilitate padding and upholstery to the requirements of the child
- * provision of a large fully adjustable tray that can be easily shaped to the child's needs
- * a two position tilt mechanism for the seat and footrest
- * several different control options for the wheelchair including head controls, touch controls and joystick controls

Figures 'D' show the most recent development of the Centre, a "Go Cart" for younger cerebral palsied child. As with the above chair the design incorporates excellent supportive surfaces including an encircling tray, that are easily fashioned to suit the child.

The chair has been designed to encourage a young child's motor development through a variety of positions and controls. Of particular interest is the ability of seat to be unfolded so that the child can drive the chair from a prone position. Although the Go Cart was conceived for the young cerebral palsied child it is also being used by spina bifida and multi-handicapped children.

CONCLUSIONS

The New Zealand Disabilities Resource Centre has developed a range of specialised children's wheelchairs which are easily adapted to the requirements of the more severely disabled child. Further information pertaining to these wheelchairs can be obtained by writing to the author: The New Zealand Disabilities Resource Centre, 840 Tremaine Avenue, Palmerston North, New Zealand.

ACKNOWLEDGEMENT

This work is the outcome of co-operation between a large number of individuals who work for the New Zealand Disabilities Resource Centre. Significant contributions were made by Mr Rae Cooke and Mr Richard Lockett whose engineering experience and skills were instrumental in the development of these chairs.

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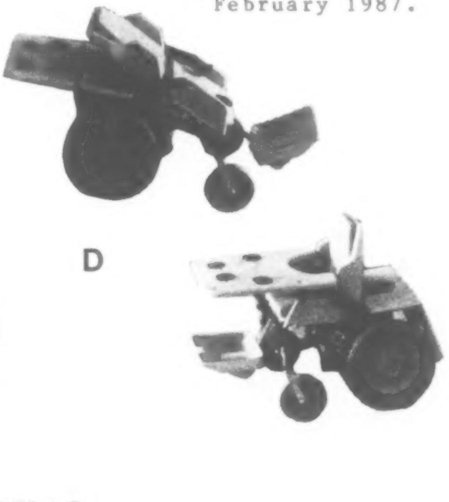

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TESTS OF A NEW FOAM POLYURETHANE WHEELCHAIR TIRE

John R. Gordon, Jr., B. S., James J. Kauzlarich, Ph.D.
and John G. Thacker, Ph.D.

I. INTRODUCTION

This paper addresses a number of important tire performance characteristics in order to make a comparison of three types of tires; a foam polyurethane tire, a solid polyurethane tire, and a rubber pneumatic tire.

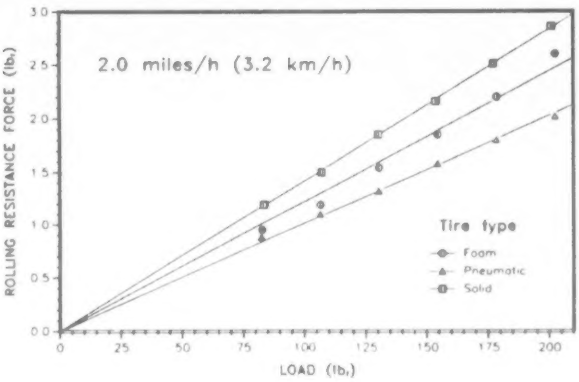
Polyurethane Foam Tire
    Distributor: Everest & Jennings Corp.
    Hardness Shore A: 72
    Cost to consumer: Part 90000A01, $14.
Solid Polyurethane Tire
    Distributor: Invacare Corp.
    Hardness Shore A: 80
    Cost to consumer: Part B1210D-5, $41.60.
Pneumatic Tire
    Distributor: Everest & Jennings Corp.
    Hardness Shore A: 75
    Cost to consumer: Part WT-24P-T-137P-G
        $32.80 (tube $7.30)

II. ROLLING RESISTANCE

The rolling resistance of each tire pair was measured using a treadmill and load cell test facility. Pairs of 24" tires were tested using a towed cart arrangement. Camber and toe were adjusted for zero degrees and measurements were taken at various speeds and loads. The wheel bearings were adjusted for minimum drag; the measured bearing torque is 0.015 lbf-in, and has a negligible effect on rolling resistance.
The rolling resistance of the pairs of tires varied with both load and speed. The treadmill was operated at speeds of 1.5, 2.0, and 3.0 miles per hour (mph), and rolling resistance was measured for loads of 85, 109, 133, 157, 181, and 205 pounds (lbf) for each speed setting. The effect of speed on rolling resistance was small in the range tested.

As shown in Fig. 1, the rolling resistance of the foam tire could not match that of the pneumatic tire. The pneumatic tire's rolling resistance was 17% lower than that of the foam tire with the low load (80 lbf) condition and the gap continued to widen to 19% lower at larger loads (200 lbf). The pneumatic tire rolling resistance from Fig. 1 is 0.010 lbf/lbf(load) per tire. The rolling resistance of the foam tire is 0.012 lbf/lbf per tire.

Figure 1: Tire Rolling Resistance vs Load



III. SPRING CONSTANT

Spring constants (Table 1) were measured using a standard load testing device (Instron Model 1122 Universal Testing Instrument). A load was gradually applied and deflection vs total load was plotted by the instrument. The spring constant was then calculated by dividing the total force by the total deflection.
The tire, rim, and test fixture were loaded as a whole. The rim and test fixture together and the test fixture alone were also tested so that the tire spring constant could be separated from the system as a whole.
Tests were made for each tire in two ways. First, the force was applied along one of the "mag" wheel spokes and second, the force was applied between a pair of spokes. Theoretically the value of the tire spring constant should be the same regardless of which test position is used. This was not always the case and is attributed to the difference in load transfer between tire and rim. The pneumatic tire acts on the edge of the rim while the airless tires transfer load to the rim edges and center.

Table 1: Tire Spring Constant

Tire Type	Spring Constant (lbf/inch)	
	Along Spoke	Between Spokes
1. Foam	1603	1185
2. Solid	3976	2960
3. Pneumatic	694	654

IV. ROLL-OFF

Roll-off angle was determined by towing the cart with the toed out tire pair on the treadmill. The toe angle was varied and the tire inspected for roll-off. For a given angle of toe, if the tire separated from the rim to such an extent that the tire did not return to its normal position on the rim when the toe angle was reduced to zero, a failure would be recorded. The maximum angle that can be tested with our apparatus is 12 degrees of toe.

No roll-off failures were recorded for either the foam tire or the solid tire up to the 12 degree maximum toe of our equipment. The pneumatic tire was not tested for roll-off.

V. IMPACT

To get a feel for the impact absorbing ability of each tire type, the tire pairs were towed on the treadmill at a speed of 1.5 miles per hour (mph) with a cart load of 157 pounds. An ISO standard "slat" (2) was attached to the treadmill belt and allowed to impact both wheels of the cart at the same time. The acceleration response of the test cart in both the horizontal (front to back) and vertical direction was measured using piezoelectric accelerometers. See Table 2 for results.

Table 2: Tire/Wheel/Load Acceleration Response

Tire Type	Peak Acceleration (G's)	
	Horizontal	Vertical
1. Foam	0.41	1.57
2. Solid	0.89	1.67
3. Pneumatic	0.23	0.77

VI. WEAR

The wear resistance of the various tire materials was compared using a method similar to that described in ASTM D 1630-83 (Rubber Property - Abrasion Resistance). The following modifications and changes were made to the ASTM procedure. First, our abrasion test machine directly applied the load and only one sample is tested at a time. Second, a coarse grit (# 80) emery paper (aluminum oxide) was used as the abrasive. Third, a vacuum system was the only method employed to clean the abrasive surface.

Following the procedure of ASTM D 1630-83 an abrasive index was calculated (Table 3) using the following formula: Abrasive Index = R1/R2 x 100 where: R1 = number of revolutions required to abrade 0.1 inch of the test specimen, and R2 = average number of revolutions required to abrade 0.1 inch of the reference compound before and after the series of test specimens.

Table 3: Tire Material Abrasive Index

Tire Type	Abrasive Index
1. Foam	208
2. Solid	72
3. Pneumatic	416

VII. COMPRESSION SET

The three tire types were tested for their resistance to compression set following the procedure of ASTM D 395-85 (Rubber Property - Compression Set) Method B, Compression Set Under Constant Deflection in Air.

The ASTM test was modified as follows to make this test more applicable to wheelchair tires. The tire was tested in place on its rim. The compression anvil chosen was a 1/2 inch diameter rod similar to that used for most wheelchair parking brakes. Each tire was compressed 4.8 mm for 22 hours at 72 degrees Fahrenheit and then released. The maximum compression deflection remaining in the tire after 30 minutes was recorded and the compression set is then expressed as a percentage of the original deflection.Table 4 gives the results.

Table 4: Compression Set Test

Tire Type	% of Original Deflection
1. Foam	3.2
2. Solid	21.2
3. Pneumatic	10.6

VIII. DISCUSSION OF RESULTS

While this new foam tire is unable to completely match pneumatic tire ride characteristics, it is a definite step closer to the goal of an airless tire which meets the performance standard set by the pneumatic tire. And, it is an improvement over solid polyurethane tires. Of course, the airless tires have a great advantage of being maintenance free for the life of the tire.

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University of Virginia Rehabilitation Engineering Center, Charlottesville, Virginia, USA 22903 NIHR Grant No. G00-83-00072

ESTIMATION OF BATTERY STATE-OF-CHARGE DURING CHARGING USING THE CHARGE RECOVERY PROCESS

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INTRODUCTION

When the charging of a battery cell is interrupted following the reintroduction of some amount of energy into that cell, it is observed that the open-circuit voltage (OCV) (termimal voltage under no-load) drops quite rapidly initially. Over the course of time, the rate of this drop decreases significantly and eventually, the OCV reaches an equilibrium value. This phenomenon has been named "recovery"[1]. This stablized OCV has been shown to be directly proportional to the battery's state-of-charge and has been considered for purposes of battery condition monitoring.

A new method for predicting state-of-charge after discharging was developed at the UVA Rehabilitation Engineering Center, based on the recovery process [2]. The method utilized the slope of the recovery process during the initial minutes of recovery to estimate the current battery state-of-charge. It was found, however, that the recovery curves were quite different after the charge process and the discharge process. A small period of discharge time was required after a charging period in order to use the technique.

The properties of the charging process have been studied. In this paper, a method is introduced that has potential as a technique for the estimation of the battery state-of-charge during the charge recovery process. Accurate estimation of the state-of-charge during the charging process is important so that the charger can be removed before overcharging takes place, a situation that can decrease the lifetime of the battery.

THE RECOVERY PROCESS AFTER CHARGING

During the charging process, generation of acid within the pores of the plates results in a skewed distribution of acid ions across the width of each individual cell. At the time of charger circuit interruption, the acid concentration will be highest at the electrode-electrolyte interface and lowest at the center of the cell. This is due, for the most part, to the generation of acid within the plate area and the slow diffusion of acid away from the plate during charging. Also, a factor in the generation of this distribution is that prior to the time when gassing begins, the heavier sulfuric acid will settle to the bottom of the cell and remain near the electrode relatively undisturbed.

When the charging circuit is interrupted, the production of acid at the plates ceases. It is presumed that diffusion then becomes the dominant activity within the cell and the acid concentration at the plate falls rapidly. Although diffusion is presumed to be the dominant activity, there is some question as to the size of its contribution and that of other factors. Other factors contributing to the terminal voltage during charge are the ohmic, concentration, and activitation overvoltages.

If, however, the cell is allowed to sit, the difference between the concentration at the plate and at the cell mid-point will, over a period of time, become less and less as the acid is given a chance to diffuse evenly throughout the cell. Eventually, the cell concentration will reach an equilibrium.

The exact length of this stabilization period, however, is a matter of some discussion [3]. There have been conflicting reports about the stabilization period required following a charge. This is expected since the recovery of a battery may vary with the size and structure of the cell. Tests at UVA have shown that equilibrium had not been reached after nearly seven (7) days, a much larger time than needed for recovery after discharging. The physical structure of the plates may have a significant effect on the length of the recovery process. As plate designs are modified to resist shedding by reducing direct contact between the active materials and the electrolyte, the ability of ions found deep within the plate structure to migrate to the electrolyte may be inhibited. This delay will increase the time required for the acid distribution to reach a steady-state or equilibrium condition.

BATTERY TESTING

Bench testing of different batteries was conducted, First, the batteries were discharged and allowed to stand for several hours following the discharge to allow the batteries to recover before the charging process was begun. The batteries were then charged to some pre-determined state-of-charge and the recovery monitored after the charger was removed. The recovery process was monitored for 10,000 minutes (6.9 days). The same procedure was repeated for several levels of returned capacity (60%, 80%, 90%, and 100%). The returned capacity was determined by counting ampere-hours.

Two sets of batteries were tested, both of which were of the liquid electrolyte type. One of the sets consisted of standard deep-discharge batteries (NAPA 22NF) while the other set was constructed of positive plates that incorporate a new tubular design. This design tends to reduce the amount of shedding, a result of overcharge, and have been shown to have a significantly longer life expectancy than ordinary flat plate batteries [4]. The recovery curves for the new design are shown in Figure 1. The recovery curves for the standard batteries differed only in the values of the actual voltage measurements.

RESULTS

Initially analysis of the characteristic curves was based on the assumption that the diffusion of the electrolyte dominated the recovery process as was the case for the recovery process after discharging. It was shown that the diffusion equation could not be used to model the process. It was found, however, that the recovery curves produced were extremely linear during the initial minutes of recovery. Additionally, it was found that the slope of the curves increased as the battery state-of-charge, at the time of charger circuit interruption, increased. The most promising characteristic of these curves is that the relationship between slope and state-of-charge is relatively identical for either of the batteries tested.

The viability of this method is heavily dependent upon the relationship between the slope and the state-of-charge being maintained irrespective of battery type. Considering the differences between the types tested, the ability to maintain this relationship looks promising.

Slope versus OCV results are shown in Figure 2. The slope used for these calculations is the difference between the OCV after 1 minute of recovery and 10 minutes of recovery. A series of discharge/charge/recovery cycles were performed at various states-of-charge to assess the accuracy of this kind of method. Several higher-order representations for the estimation of these curves were used, in addition to the linear equation. The root mean square error for the four fitted curves ranged from 2.15% to 3.60% with the linear representation having an error of 3.09%. Maximum error for the various forms was 6.4%. Maximum error for the linear approximation was 5.1%.

CONCLUSIONS

The potential advantages of this method are obvious. First, temperature should not, theoretically, have any affect on the accuracy of the prediction. The amount of voltage added or subtracted due to a change in temperature should be constant over the recovery curve. While the curve will probably change position on the voltage axis, its slope over the initial 10 minutes of recovery should not be affected. Second, while age may, again, shift the position of the curve, the slope should remain the same. Finally, the controversy, or question, of the length of the recovery process would become mute. The length of the recovery and the value of the stabilized open circuit voltage would no longer hold any importance in estimating the current state-of-charge.

There are also potential drawbacks to this method. The most significant problem is the ability, or inability, to reproduce the slope versus state-of-charge relation with a variety of battery system types. Although the dissimilar battery types tested here showed a highly similar slope versus state-of-charge relationship, it may be overly optimistic to assume that the majority of commercially available battery systems would also maintain this relationship. For example, initial tests on a gelled electrolyte battery type indicated that the slope of the recovery curve is much less at comparable states-of-charge.

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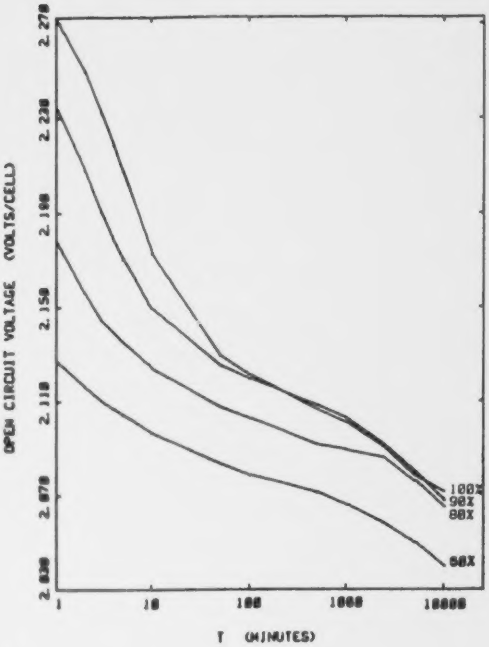

Figure 1. Recovery Curves

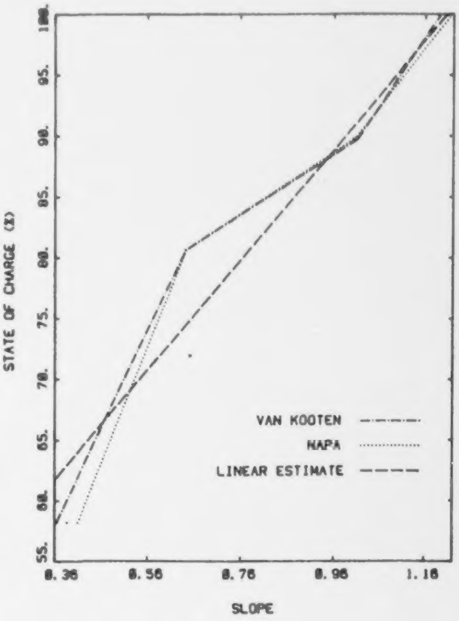

Figure 2. Slope/State-of-Charge Characteristic

A MEANS OF ELECTRONICALLY MODIFYING THE CONTROL PATTERN OF A PROPORTIONAL JOYSTICK CONTROL FOR AN ELECTRIC WHEELCHAIR

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INTRODUCTION

When patients with extreme upper extremity impairment attempt to control an electric wheelchair with one of the standard proportional joystick controls, their task is a difficult one. We believe the factors in both the mechanical and electronic design of the controls which cause the major problems are identifiable and correctable. The focus of this presentation is the problem caused by the control pattern generated by the joystick.

PROBLEM ANALYSIS

The joystick is basically a rod that is pivoted at one end with the distal end free. The rod is mechanically coupled to two linear potentiometers or similar devices. The potentiometers are arranged at a right angle to each other and each is at 45 degrees from the forward direction of wheelchair travel. The rod is held in a vertical position by a spring mechanism, its distal end being the control end. It has a range of motion from zero at rest (center) to a maximum radius determined by the mechanical limits of the system.

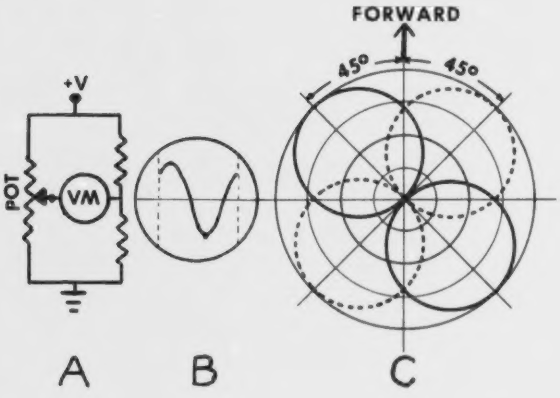

Figure 1

A plot of the control pattern is necessary for understanding this problem in controlling the wheelchair. The circuit in Fig.1-A is used for plotting purposes. The output of only the potentiometer which controls the left motor is observed. When the rod is pushed forward to a point between zero and its maximum excursion and its distal end is made to inscribe a circle of constant radius around the center, the voltage output of the potentiometer measured against degrees of rotation is a sign wave which starts at its 45 degree point (71% of peak value) as shown in Fig. 1-B.

If the outputs of both potentiometer are plotted on polar coordinate paper the result is two figure eight patterns that are displaced by 90 degrees as shown in Fig. 1-C (left motor dashed and right motor solid). (Remember, the right motor controls left turns and the left motor controls right turns). The important observation is that, in the forward direction, only about 71 percent of the maximum voltage is applied to each motor. Consequently, when the patient attempts to make a slight turn correction, one motor greatly speeds up while the other slows down thereby exaggerating the effect of the correction. This is further complicated because most people, when making a turn, move the stick directly right or left rather than follow the original radius. Since this is actually moving the stick further from the center, the chair will move even faster in the turn. This causes very erratic steering, particularly for first time users. Although most patients eventually compensate, some cannot and are forced to use a different system.

There is also an inactive zone built into the systems whereby no power is applied to the motors until the stick is moved a predetermined amount in any direction. This is done to prevent unintentional operation of the chair when the hand is first placed on the control. However, if the control is slightly off the forward direction when the patient starts out, one motor receives power and not the other. This causes the chair to start to turn in the opposite direction of the motor

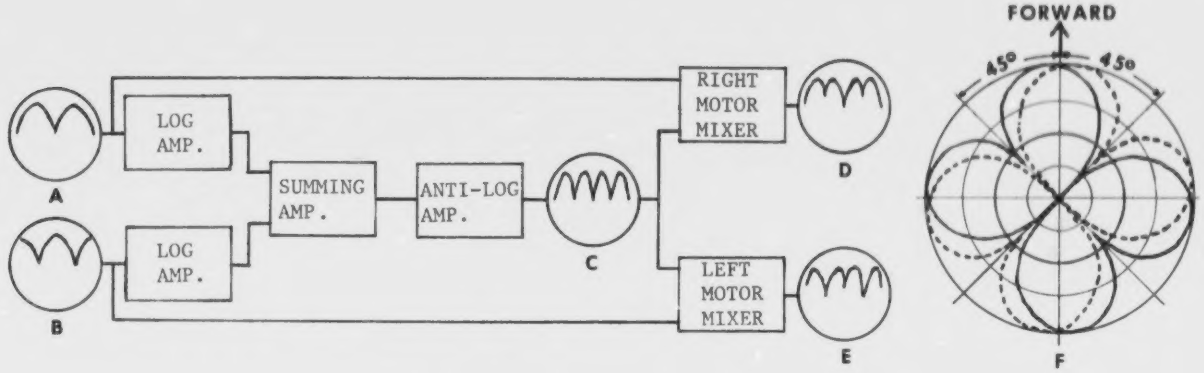

Figure 2

receiving the power. At higher speeds the peaks of the sign waves are clipped in order to apply full power to both motors when the stick is in the full forward position. This actually improves steering at these speeds. Unfortunately, this has no effect at lower (starting) speeds.

SOLUTION

When the output of each potentiometer of the joystick is rectified and then multiplied, the result is the second harmonic of the original. When this is then mixed with the rectified outputs of the individual potentiometers, the shape of the control pattern can be altered by varying the proportions of the mix of the fundamental and second harmonic. The original pattern is still used to determine the direction of rotation of the motors. Mutiplication is easily accomplished through the use of log and anti-log amplifiers. A block diagram of the circuit is shown in Fig. 2. A is the full wave rectified output of the right motor potentiometer and B is the full wave rectified output of the left motor potentiometer. The logs of A and B are summed and the anti-log obtained which produces the product of A and B as shown in C. C is then mixed with A with the result D and with B with the result E. F is the result in polar coordinates. This is close to what we consider the ideal control pattern.

DISCUSSION

We have designed and constructed an evaluation system in order to test the above stated hypothesis as well as some hypotheses on the mechanical limitations found in many systems. In its present form it interfaces with a specific chair. It should be possible to interface it with any joystick control system. Among its features are the ability to switch between a standard joystick and one that has been compensated against the effects of gravity. The control pattern is selectable, allowing one to optimize for a particular patient.

CONCLUSIONS

The problems associated with the control pattern generated by the standard joystick proportional control are described. A means of modifying this pattern is presented which, we believe, solves at least one problem associated with this type of control.

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Early Mobility Utilizing the Hedstrom Probe VI

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Abstract

Early mobility has been shown to be important in the cognitive and psychosocial development of children. Various devices have been developed in order to provide independent mobility for very young disabled children. Some of these devices involve the use of toy vehicles commonly available to consumers. The present paper describes modifications made to a Hedstrom Probe VI which allows the use of a variety of switch inputs through a standard nine-pin connector. The design of the electronic modifications has implications for easily accommodating a variety of functional abilities for different children or as a single child grows.

Introduction

The importance of independent mobility in the psychosocial and cognitive development of disabled children has been established. Commercially available powered wheelchairs, if available for very small children, are prohibitively expensive. Powered carts have typically been custom designed and fabricated for an individual, hence the cost is often prohibitive.

Addressing the problem of cost, the Rehabilitation Engineering Lab at the University of Texas investigated the use of 'toy' carts as means of providing the child with independent mobility (1). The investigation demonstrated feasibility with a Coleco Corp., G.I. Joe and the Hedstrom Corp., Probe VI. Coleco's cart had to be customized with the addition of a 'joystick' to control movement. Hedstrom's toy vehicle contained a joystick which made it very easy for many children to control the vehicle. The total cost of the Hedstrom cart was $170.00

Unfortunately, the joystick provided with the Probe VI is not adequate for the functional abilities of many children. Hence, more modifications with associated costs. Technical Aids and Systems for the Handicapped (TASH) Inc. distributes a variety of 'multiple switches' which may be used as the control devices for a motorized cart. A circuit has been designed that can accommodate the variety of switches distributed by TASH thereby enabling the clinician to test the child's capability in operating the cart without redesigning the electronics each time. The concept is that one inexpensive modification could be used for a variety of functional abilities.

Definition of Problem

In order to provide independent mobility for a 2 1/2 year old girl with cerebral palsy a Hedstrom Probe VI cart was obtained. Her limited strength precluded her from using the standard joystick. It was discovered that she could operate a short-throw joystick from TASH. An electronic circuit was designed to replace the probe's switching joystick and accommodate the TASH joystick. The standard joystick allows four directions of travel; forward, reverse, left and right and two speeds. The modifications made to the cart allow it to travel in eight directions; forward, forward-right, forward-left, left, right, reverse-left, reverse-right and reverse. The circuit can be modified to accommodate various functional abilities and mobility needs.

Technical Description

Power and motor interconnects are made using solderless terminals as in the unmodified cart. The circuit receives either a 6 volt or 12 volt power signal (VBAT+ referenced to VBAT-) when a dash board switch is activated. Inputs, via a 9-pin D type connector, from the switch are logically 'ORed" to produce a logic '0' at the gate of the P channel MOSFET (Q1). In turn, Q1's source to drain resistance switches from high resistance to very low (R_{ds}) ON is approximately 0.6 ohms), like a switch. When this switch is 'on', the linear regulator (VR1) creates a 5 volt (VCC) signal from the 6 or 12 volts. In english, "if any of the switches are on, then the VCC signal becomes 5 volts, else, VCC is 0 volts".

As depicted in the schematic, the TASH control switch inputs are 'pulled up' (R10-R13) to the VBAT+ voltage. Upon activation, these switches pull connect the signal (-FOR,-REV, -RIGHT,-LEFT) to ground, creating a logic '0' as seen by the buffer/converter (U2). This device converts the signals to TTL logic levels and complements the signals for input to the GAL. As a note, the GAL requires 'TTL' level inputs.

The two motors of the electric cart are driven from VBAT+ signal using standard Aromat relays which are rated for the inductive load (DC motor). When the NPN transistor is in saturation its corresponding relay is activated. This occurs with a logic '1' present on the output of the GAL^{tm} (Generic Array Logic, manufactured by Lattice Semiconductor). The logic contained within the GAL allows the cart to operate in 8 possible directions. (See schematic for equations.)

Modifications to Circuit

If the developer cannot program a GAL or a PAL^{tm} (Programmable Array Logic, similar to a GAL except not reprogramable), discrete logic can be used. It is suggested that logic from the RCA CD4000 series be used since it can be powered by a supply from 3 to 15 volts. If only one direction is input at a time (from a gated type joystick), then the logic may be further reduced. The logic equations presented in this paper are already minimized.

Power MOSFETs could be used in place of the single pole double throw relays. Note that a gate to source voltage of greater than 5 volts (negative for P-type) is required for the (approximately) 5 amps transient and 2.5 amps continuous motor load. Therefore, if this approach is taken, CMOS logic (with a high voltage output, Voh) should used to drive the gates.

Note: If the transient inductive load of the motors 'pull' the battery supply below the VR1's minimum regulation voltage the GAL will NOT operate properly.

Summary and Conclusions

An electronic circuit has been developed for an inexpensive toy cart enabling it to be driven by a variety of switch inputs, particularly TASH switches. The circuit can be modified to accommodate various functional abilities and mobility needs. Control systems of powered wheelchairs may be made more flexible such that they may be modified by a clinician as the user becomes more proficient in their use.

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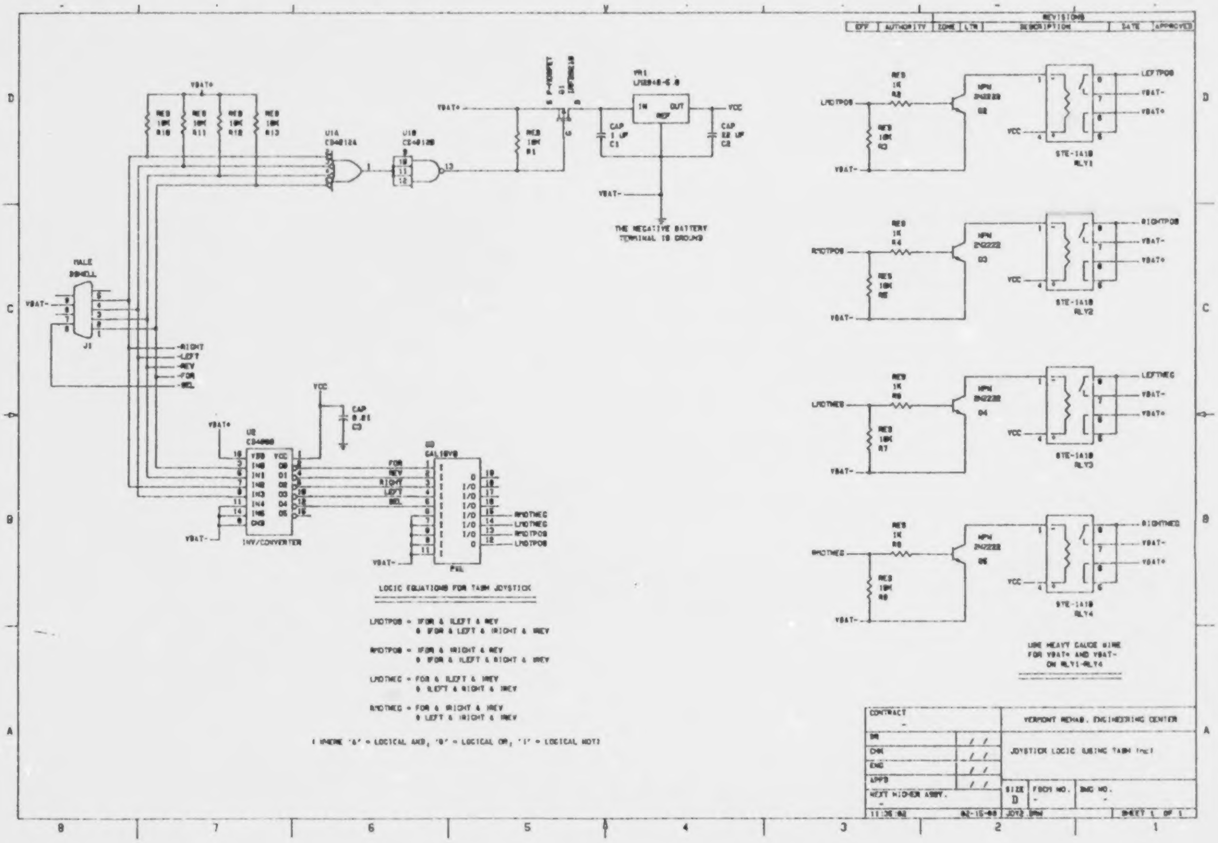
LOGIC EQUATIONS FOR TASH JOYSTICK
LMOTPOS = !FOR & !LEFT & REV # !FOR & LEFT & !RIGHT & !REV
RMOTPOS = !FOR & !RIGHT & REV # !FOR & !LEFT & RIGHT & !REV
LMOTNEG = FOR & !LEFT & !REV # !LEFT & RIGHT & !REV
RMOTNEG = FOR & !RIGHT & !REV # LEFT & !RIGHT & !REV
(WHERE '&' = LOGICAL AND, '#' = LOGICAL OR, '!' = LOGICAL NOT)
MALE DB9ELL
J1
-RIGHT
-LEFT
-REV
-FOR
-SEL
VBAT+
VBAT-
VCC
U1A CD4012A
U1B CD4012B
VR1
IN
OUT
REF
CAP 1 UF C1
CAP 22 UF C2
CAP 0.01 C3
THE NEGATIVE BATTERY TERMINAL IS GROUND
U2 CD4050
INV/CONVERTER
U3 GAL16V8
PAL
RMOTNEG
LMOTNEG
RMOTPOS
LMOTPOS
LEFTPOS
RIGHTPOS
LEFTNEG
RIGHTNEG
NPN 2N2222
STE-1410 RLY1
STE-1410 RLY2
STE-1410 RLY3
STE-1410 RLY4
USE HEAVY GAUGE WIRE FOR VBAT+ AND VBAT- ON RLY1-RLY4
REVISIONS
VERMONT REHAB. ENGINEERING CENTER
JOYSTICK LOGIC USING TASH INC.
CONTRACT
DR
CHK
ENG
APPD
NEXT HIGHER ASSY.
SIZE D
SHEET 1 OF 1
8
7
6
5
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2
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D
C
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A

Modeling of an Electric Wheelchair System

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ABSTRACT

This paper presents work done towards the development of a software system to facilitate the study of reliability, availability, and safety for electric wheelchairs. The software package is also aimed at supporting designers who wish to integrate reliability analysis with the design process. Using the software, the designer is able to predict the performance of the wheelchair system and study the effect of different component characteristics.

INTRODUCTION

An important link in the proper development of an improved electric wheelchair, such as a proposed microprocessor-based system [1], is the reliability analysis of the wheelchair design [2]. Ideally, reliability analysis and wheelchair system design should be performed concurrently such that design decisions can be evaluated and their impact on wheelchair reliability determined. Various reliability modeling techniques have been developed for the analysis of systems [3]; however, most of the analysis tools are focused towards the modeling of large and ultra-reliable systems. As a result, they require the user to be well-versed in reliability modeling techniques and are often developed for use with mainframe computers.

The goal of the work presented here is to develop a reliability analysis software package for application to the electric wheelchair. The software is targeted for the personal computer environment and allows the user to model the wheelchair at different levels of detail, from a system-level decomposition with the system broken into the main functional stages to the modeling of redundant components within the stages.

MODELING THE WHEELCHAIR SYSTEM

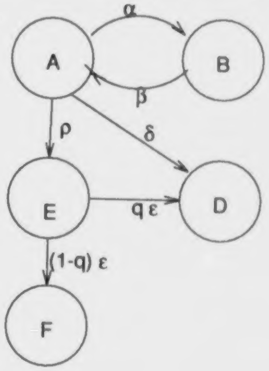
To model any system and study its fault-tolerant aspects one can take two approaches, *structural decomposition* or *behavioral decomposition*. In structural decomposition the system is broken into smaller subsystems, and the reliability of the system is found as an aggregate of the subsystem reliabilities. Structural decomposition is valid as long as the subsystems are independent of each other in their failure and fault recovery mechanisms. In the behavioral decomposition, the fault handling behavior is managed separately from the fault occurrence behavior [4]. The fault handling model is solved and the parameters are incorporated into the fault occurrence model. The software package presented here uses both the structural and behavioral decomposition.

Inherent independence between stages in the wheelchair is used to make a structural decomposition at the highest level. First, the wheelchair is divided into an electrical and mechanical system, and the electrical system is further divided into different stages that are assumed to be in series, as far as reliability is concerned. The typical stages of the electrical system include: (1) the user command sensors, (2) motor feedback sensors, (3) controller electronics, (4) motor drive electronics, and (5) the electric motors [5]. The user can define more stages as the need arises, but all the stages at the highest level are assumed to be in series.

The second step is to model each of the defined stages. Each stage can contain different component types, some of which may be redundant. For example, the electronic controller may contain two central processing units (CPUs), two memory boards, and one input/output (I/O) unit. To model each stage, the user has the option to further decompose the stage, if possible, into substages that are independent in their failure and recovery mechanism. The user will eventually reach a situation where further decomposition is not possible. When further decomposition is not possible, the user can specify the configuration of the stage or the substage using a fault tree which is internally converted into a Markov model for analysis. The software also offers the user a library which has standard fault-tolerant architectures such as N-modular redundancy (NMR) and duplication with comparison [3]. The user can choose one of the standard models to describe a stage or substage and simply enter the required parameters.

PRINCIPLE OF OPERATION

The behavioral decomposition is specified at the lowest level. The fault occurrence model conveys information about the structure of the hardware redundancy and failure rates. The fault handling model, shown in Figure 1 [3], is used to model permanent and intermittent



A: fault active, capable of producing errors.
B: fault benign, unit temporarily functioning properly.
D: fault detected and recovery complete.
E: fault has produced an error.
F: system due to error propagation.
α: fault becomes active, capable of producing errors.
β: fault becomes benign.
ρ: error production.
δ: detection and recovery.
ε: error propagation.

Figure 1: Fault handling model used in software package.

faults and the recovery procedure from these faults.

The Markov model resulting from the fault tree for an example electronic controller is shown in Figure 2. The fault handling model, shown in Figure 1, is solved for the coverage parameters [2] and inserted in the fault occurrence model, which is solved for the reliability of the defined stage or substage.

To model the motor used in the wheelchair, the user can employ the life expectancy rate available from the manufacturer or use a model made available in the software package. The model available in the software package is as shown in Figure 3. The model is based on the fact that the motor's failure rate is influenced by the amount of time spent in the overstressed state; that is, the motor is operated above the specified current, voltage, or temperature range.

Methods for modeling the mechanical system of the wheelchair using Markov models with time-dependent transitions are currently being examined. Feasibility and details of the model are being worked out and will be incorporated into the software package.

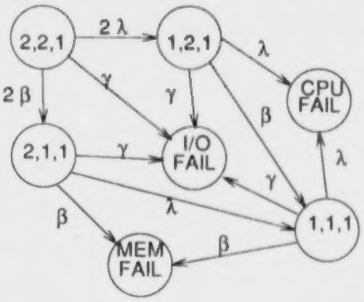
USER INTERFACE

The software package is menu driven for easy interaction. A summary of a typical session would be as follows; (1) the user chooses the option from the main menu to enter the system parameters, (2) the user enters the number of stages and the name of each stage, (3) each stage is modeled using a model stored in the library or one created using a fault tree, (4) the model is solved, and (5) the user can display the results in numerical or graphical form.

The current software program is written in the C programming language and is undergoing development and testing. The intent is to have a package that can execute on a personal computer. A conscious effort has been made to keep the model simple yet flexible, and the user is not expected to be well versed in fault-tolerant modeling techniques.

CONCLUSIONS

The research presented in this paper is directed towards the development of a highly-interactive software package to support analysis during the design and evaluation of electric wheelchairs. The software package is being developed to run on a personal computer so that widespread use will be possible. The techniques have been demonstrated and future efforts will focus on further refining the software and performing an extensive evaluation of the concepts.

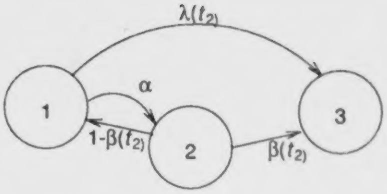


λ: failure rate of CPU.

β: failure rate of memory boards.

γ: failure rate of I/O unit.

Figure 2: Markov model for an example electronic controller.



State1: Motor operating within specified operating conditions of current,voltage and Temp.

State2: Overstressed state, motor operating over specified conditions.

State3: Failed state.

$\lambda(t_2)$: Failure rate of motor that is dependent on the amount of time spent in state 2.

$\beta(t_2)$: Failure rate of motor when operated in stressed state. It is dependent on the amount of time spent in state 2.

α: Transtition rate to the overstressed state.

Figure 3: Model of electric wheelchair motor.

ACKNOWLEDGEMENTS

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Lever Drive System for Wheelchairs

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ABSTRACT

Lever drives provide greater mechanical advantage, and a fun alternative, to wheelrim propulsion of wheelchairs. The purpose of this project was to produce a lever operated wheelchair for outdoor use. This paper describes the new lever drive system.

INTRODUCTION

Handrims are the standard means of propulsion on wheelchairs designed for paraplegics. They provide excellent manuverability, and power, in close quarters. However, handrims do not offer the same efficiency when traveling long distances, or when going up inclines - racing wheelchairs being the exception. It has been shown that the reciprocal operation of lever arms mounted on a wheelchair offers an increased mechanical advantage, and an increased efficiency, over handrims.[1]

Current Systems

There are a variety of U.S. patents on lever drive mechanisms.[2] Unfortunately, none are commercially available. To the best of our knowledge, the MYRA is the only double lever drive commercially available in the U.S. (Arnas-Porierier and American Vermeiren manufacture single lever drives for hemiplegics.)

The MYRA uses an off-centered bell crank. While offering a double lever drive, it does not freewheel: the rider must continue to pump the levers and cannot rest. It is also difficult to start from a dead stop when the levers are at their limits of motion due to the dead spots. Another disadvantage of the MYRA is its single speed due to the fixed mechanical advantage.

Design Criterion

The design team sought to build an outdoor wheelchair with more speed, power, and efficiency than currently available through conventional wheelchair handrims. An experienced wheelchair user should notice an immediate improvement in efficiency and feel when comparing the new lever drive system to handrims. The new mechanism should be simple, inexpensive, easy to build, and fun to use. Together with Ken Hawkins, a T-4 paraplegic with 28 years of experience in riding and modifying wheelchairs, the design team set out to achieve these goals.

DESIGN METHOD

In addition to the design criterion, the following specifications were decided on:

1. The levers should power the wheels in both push and pull strokes;
2. A neutral should exist to provide the user with the option of disengaging the drive mechanism for handrim usage;
3. The mechanism should freewheel to allow coasting; and,
4. It should be easily adaptable to existing wheelchairs.

Procedure

Different lever drives were tested by the design team. These shairs were: MYRA, Lucken, American Vermieren, and the current lever drive from the University of Virginia.

After reviewing the various chairs, and studying available patents, the mechanism to be used with the lever drive was narrowed down to one of four catagories:

i. Roller clutches, such as those made by Torrington and Sprague;
ii. A gear and gear rack configuration;
iii. A freewheeling bell crank; and,
iv. A double ratchet system.

The double ratchet was selected as the mechanism of choice due to its simplicity and low cost.

DESIGN SOLUTION

The completed chair, with the handrims detached, is shown in figure 1. The lever drive system was tested and built on a Quadra-Fold wheelchair. In the final design (figure 2) two pawls are used to push a ratchet. The ratchet is mounted onto the rear wheel hub. During the forward stroke, the upper connecting link pushes the upper pawl, engaging the ratchet. At the same time, the lower connecting link pulls the lower pawl, disengaging it from the ratchet. When the lever is pulled back, the lower pawl engages the ratchet, and the upper pawl is disengaged. During operation, the mechanism makes a clicking sound similar to a freewheeling 10-speed bike.

When the lever is in the full rearward position, tabs mounted onto the pawls contact each other, disengaging both pawls off of the ratchet.(figure 3) With both pawls disengaged, the user is free to use the handrims.

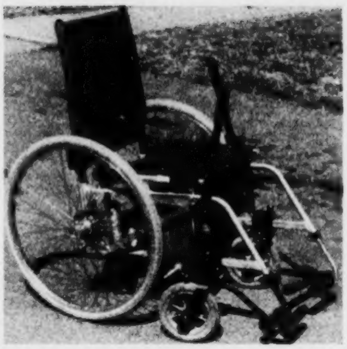

Figure 1
The finished product

Each lever is made with telescoping tubing, which provides for variable mechanical advantage, and easy transfer to and from the chair. (figure 4)

The ratchet and pawl assembly mount onto a quick-release wheelchair hub. The lever is attached to an aluminum plate with a quick-release pin. The lever drive system could be installed on other wheelchair systems with modifications to the clamping blocks on the aluminum plate.

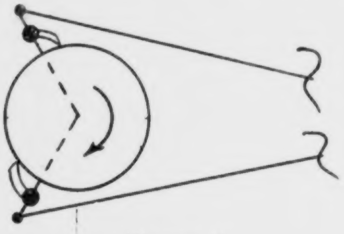

Figure 2
The ratchet mechanism

Production
Testing is currently underway in preparation for manufacturing.

Materials
For economy, Sears Panel circular saw blades were used as the ratchet: 3.375" O.D. with 100 teeth. The next generation ratchet will be made from 3/8" Delrin. The pawls are 714 stainless steel from W.M. Berg Inc. The levers were made from 7/8" x 0.049" CREW steel and 3/4" x 0.049" CREW steel. The connecting links are 1" x 1/4" 6061-T6 aluminum.

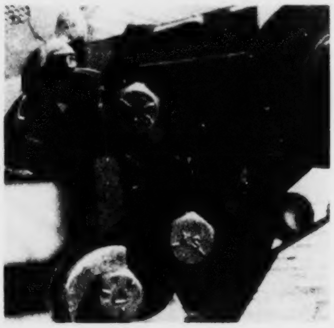

Figure 3
Tabs mounted on pawls

RESULTS

The system functions as expected: it provides greater speed with less effort in comparison to conventional handrims. Climbing grades is also noticibly improved.

It is possible to tip over backwards when applying large forces to the levers, such as when climbing a grade, or if the pawls engage when backing up. This can be prevented by attaching anti-tip extensions to the chair. However, these extensions can cause discomfort when travelling over irregular surfaces, or when going over curbs. For this reason, many people might choose to go without the anti-tip device.

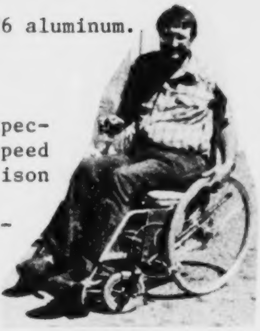

Figure 4
Easy transfer

RECOMMENDATIONS

Future developers might look into a steering mechanism for the lever drive. At present the wheelchair is steered by either adding increased power to one side of the chair, by braking on one side, or a combination of these two techniques. Another improvement might be multiple gearing, which would increase the top speed. However, it might also make the system more complex and expensive.

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A MANUALLY OPERATED STAND-UP WHEELCHAIR WHICH ALLOWS FOR MOBILITY WHILE STANDING

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ABSTRACT

This paper describes the design of an innovative stand-up wheelchair which is manually propelled in both the standing and seated positions. This wheelchair has been designed to accommodate most paraplegics.

INTRODUCTION

The numerous benefits of standing in cases of paraplegia are gaining recognition throughout the Rehabilitation Community. {4,5,6} In addition to the various medical advantages of standing, many users report a psychological boost from the ability to stand themselves up. The available manual stand-up devices are immobile in the standing mode and most are cumbersome while seated. What is needed is a manual stand-up wheelchair that is mobile in the upright position. Our design will allow the disabled "active standing" as opposed to "passive standing". We have designed and built a wheelchair that enables its users not only the benefits of increased mobility and function, but the means for a healthier body as well.

USER REQUIREMENTS

Currently, the advantages of standing mobility were only offered by the motorized devices on the market, Motostand and Standaid of Iowa. Users require a lightweight, portable, manually-operated design that they can afford. Stand-up devices should not serve as secondary wheelchairs due to poor functionalism. Paraplegics desire access to the the benefits of standing while making full and productive use of their time.

COMMERCIAL AVAILABILITY

Our market research has uncovered three manual stand-up wheelchairs: the IMEX Riser; the French Lifestand (Arise); and the LEVO Standup. Each product does achieve the desired standing position but none allow for mobility in the upright position. Our objective was to design a stand-up wheelchair that handles and performs better than the available chairs in the seated position and is capable of mobility while standing.

METHODOLOGY

The following steps were taken in the process of developing a functional design:

1. Our sponsor, Ken Hawkins, is a T4 paraplegic who provided us with a workshop, materials, and design parameters which assisted us in making a quality product.
2. Conducted user interview with a high injury paraplegic whose employer offered to supply him with the work chair of his choice. Determined qualities of wheelchair ideally suited for use in a business setting, confirming several guidelines given by K.H.
3. Researched devices which pertained to our objectives at the patent library.
4. Read publications on spinal cord injuries, seating posture, wheelchair design, and standing as it relates to spinal cord injury management. {1,2,3,4,5,6}
5. Researched the market for products representing the latest in stand-up technology. Operated two stand-up wheelchairs.
6. Modeled the frame and folding mechanism with steel. Designed the raising linkage using IDEAS Mechanism Design software package (by SDRC) in conjunction with wood models. Tested each model on the frame for the best integrated system.
7. Drew up detailed CAD drawings for prototype.
8. Made a mobile stand-up prototype.
9. Testing of the design to be completed by late April. Necessary adjustments to follow. Marketing possibilities to be pursued after prototype completes retesting.

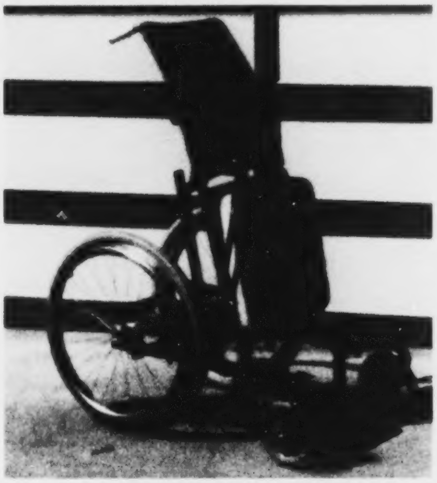


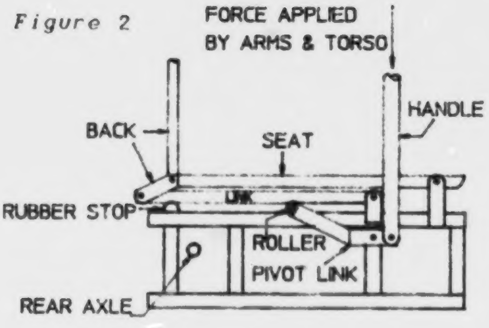
Figure 1
Standing Mode

DESIGN SOLUTION

For stability and mobility when standing the user's center of gravity needs to be positioned in the middle of the wheelbase. We allow the user to reach this central position by extending the front casters. By making use of the paraplegic's torso strength, we have developed a mechanism which enables the user to raise himself quickly and easily. A simple lever drive provides the means to propel the wheelchair when standing.

The frame consists of a dual arm folding mechanism, which is allowed to pivot about the centerline of the chair. The frame is pinned when in the open position and a completely rigid "U" shape is formed. A unique feature on the frame is the swing away front casters. These casters provide for a 7″ increase in the effective wheelbase while the user is in the standing position. A rigid footpan attaches to the frame once the base is unfolded. We have opted to use 24″ quick release rear wheels and 8″ hard front casters since they maneuver best over low rising obstacles (5″ casters will also be optional).

Figure 2



The raising mechanism consists of two basic components. The first is a four bar linkage which positions the user into the center of the wheelbase when raised. There is a ten degree inclination off the horizontal which provides greater stablility for users with higher injuries. {3} The second component is the actuator. As the user depresses this lever system he transmits his own weight into an upward motion which raises the four bar linkage (fig. 2). This upward motion is aided by the use of two 90 lb. gas springs. Our initial force analysis showed that these springs reduced the required force supplied by the user in the amount of 30 lb.

Our secondary propulsion device is a simple lever drive which tucks away between the frame and the rear wheel when not in use. The hand held portions of the lever drive will also function as the handles which the user depresses to raise himself.

CONCLUSION

Our design is a well integrated system which satisfies a large percentage of the users' requirements. We have successfully designed a folding mechanism which provides both a rigid base to the system and portability. This design distributes the users' weight so that mobility is possible while standing and functional in both modes of operation. Our system is easy to operate and requires only a partial amount of the users' strength to function. We are currently working on developing a simple but effective lever drive which will serve as the handles which raise the user as well as the means for propulsion while standing.

The final product should attain the following objectives:

1. Increase the range of mobility for the disabled.
2. Position the user within the wheelbase to establish proper weight distribution for mobility and stability.
3. Compact enough to fit behind the driver's seat of an automobile.

PROJECTED SPECIFICATIONS

1. Seat Height
   a. Front (17.5")
   b. Rear (16")
2. Total Width (23")
3. Wheelbase
   a. Sitting (14")
   b. Standing (21")
4. Folded Width (11")
5. Weight (Not to exceed 60 lb.)
6. Materials
   a. 1010 Carbon Steel
   b. Nylon Upholstery

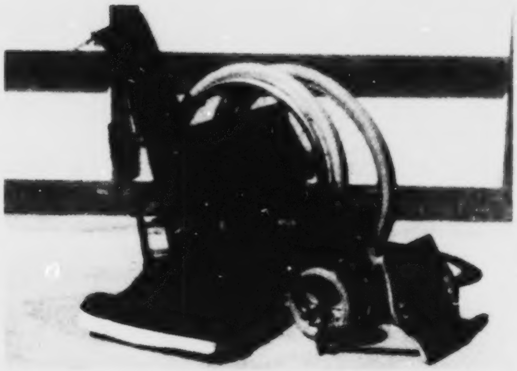


Figure 3
Folded and Disassembled

ACKNOWLEDGEMENTS

We would like to thank the individuals involved with this project for their insight and quality time: Ken Hawkins, Tim Hight, Bruce Harper, and Dwight Johnson.

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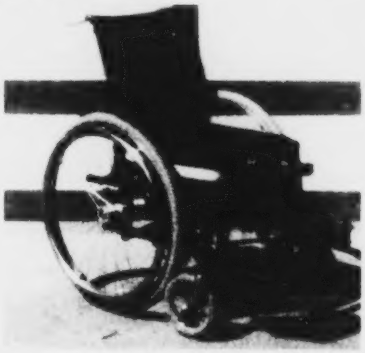

Figure 4
Seated Mode

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ANTHROPOMETRY FOR THE CEREBRAL PALSY POPULATION

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and Colin McLaurin (University of Virginia - REC, Charlottesville)

INTRODUCTION

A preliminary report (1) of this work focused on the rationale for the study and the differences between anthropometric data derived from the able-bodied (2,3) versus the physically disabled population. A trend of increasing values with age of able-bodied over disabled was clearly demonstrated. Figure 1 below illustrates the percent differences in the mean values of four parameters between the able-bodied and disabled populations.

The disability type distribution of the study population was presented. The distribution showed the cerebral palsied and spinal cord injured populations to be the largest two disability groups of the 10 categories measured. This final paper summarizes the study findings of the cerebral palsied group (N = 131) It references a comprehensive report which provides a full compliment of anthropometric data, complete with guidelines for designers who may wish to design future seating and mobility devices for the cerebral palsied population.

METHODS

Early in the study it was determined that body deformity and/or primitive reflex patterns could greatly affect the anthropometric measurements, particularly for the cerebral palsied population. Therefore, it was important to develop four additional anthropometric parameters that would capture this information for the unwary designer. The majority of the cerebral palsy subjects were measured by an occupational therapist/seating specialist while seated in their existing seating systems. It is acknowledged that the seating devices used by the individuals will have influenced the anthropometric results. However, the sitting postures and resulting measurements are considered to be typical of the cerebral palsy population that use specialized seating and mobility equipment.

The measurement sessions varies from 5 to 15 minutes. The tools used included a meter stick and an inclinometer. A weighing platform confirmed the body weight. Linear measurements were rounded to the nearest centimeter and angular measurements to the nearest degree. All data was recorded on a standardized data collection form and then entered into a MacIntosh/Excel program for analysis and presentation. In total, 84 data points were collected or computed for each of the 131 subjects in the C.P. group. The large number of data points were necessary in order to obtain a descriptive profile of the study group in terms of functional skills, control abilities, and deformity; in addition to the standard anthropometric parameters. The profile of the study group is important when interpreting the data for design decisions, or if extrapolation of the results to other populations is being contemplated.

RESULTS

There are two important results from the study. The first is the tabular and graphical presentation of the 20 analyzed anthropometric parameters. These parameters are as follows: Sitting Height, Back Plane to Back of Head, Back Plane to Under Knee, Leg Length, Foot Length, Shoulder Width, Chest Width, Waist Width, Pelvic Width, Knee Width, Occipital Pertuberance to Centerline, Acromion Height, Overall Width, Overall Width, Knee Width Midpoint to Centerline, Recline Angle, Seat to Back Angle, Seat Plane Angle, Seat to Legrest

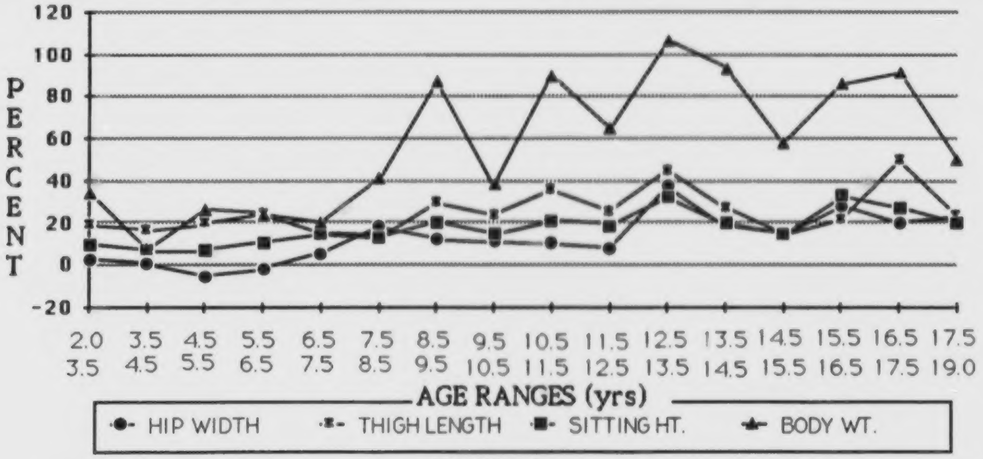

FIGURE 1

Angle, and Legrest to Footrest Angle. Figure 2 below illustrates the presentation format using the Sitting Height parameter as the example.Guidelines are presented on how to interpret the data contained in the 20 parameters, as well as the effects that deformity may have on design decision making. Also, suggestions are made on how the data from the study population may be extended for use with other populations.

The second result is an analysis of the extent of spinal and pelvic deformities that exists within the study population, and how they effect anthropometric results.

The complete results have been published in a final report entitled "Anthropometry for the Physically Disabled: Volume 1-Cerebal Palsy" which is available from the University of Tennessee, Memphis - Rehabilitation Engineering Program. The results of the cooperative work involving the spinal cord population is to be made available by the University of Virginia - Rehabiltiation Engineering Center.

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ACKNOWLEDGEMENTS

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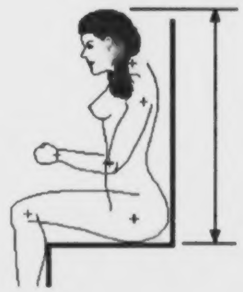
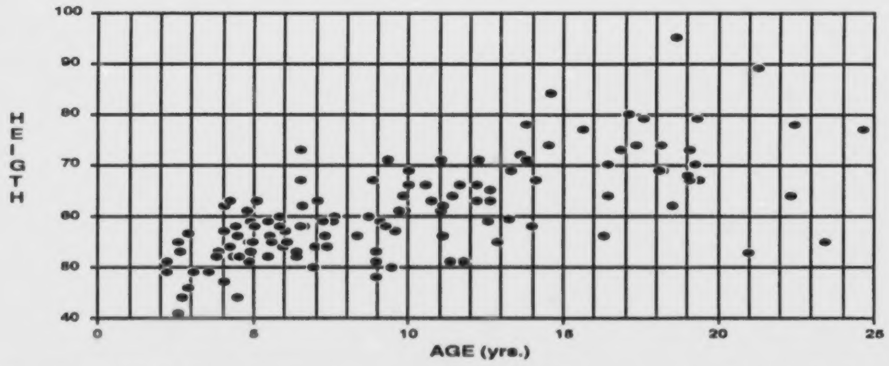
M1-SITTING HEIGHT
(cms)

AGE RANGES	NUMBER	MIN	MEAN	MAX
2-5 yrs	29	41	53	63
5-8 yrs	28	50	58	73
8-11 yrs	18	48	60	71
11-14 yrs	20	51	64	78
14-17 yrs	10	56	69	84
17-21 yrs	14	62	73	95
21-25 yrs	6	53	69	89
25-55 yrs	6	63	69	77





COMMENT : M1 is a dimension taken from side of the pelvis to the top of the head. Since the lowest aspect of the pelvis (ischial tuberosities) could not be determined in many cases, this height measurement could be as much as 5 cms. too small, especially for the older age groups.

FIGURE 2

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IN SEARCH OF A COMMON LANGUAGE: UNIFORM TERMINOLOGY FOR SEATING AND POSITIONING

Faith Saftler, PT   Susan Bachman, SPC   Cathy Bazata, OT

ABSTRACT

By using a uniform terminology regarding seating and positioning, an improved mode of communication can be established. With the development of a common language, information, ideas and research can be shared and understood by those individuals involved with seating. Therapists, durable medical equipment dealers, manufacturers and consumers can then clearly recognize and discuss critical issues inherent in the field of seating.

INTRODUCTION

An analytical approach to seating is used to determine properties needed to address goals which have been set by the interdisciplinary team for the individual. A thorough mat exam is performed followed by the use of a positioning chair. After an optimal sitting position is obtained, properties for all support surfaces are addressed.

Throughout this paper, we will be discussing seating components by describing their anatomical location, dimensions and characteristics with the use of examples.

METHODOLOGY

Anatomical Location:
Terminology is created by using anatomical terms to describe the placement of the support. These terms include body parts and positional terminology such as trunk, hip, thigh, medial, lateral, superior, inferior, anterior and posterior.

Example:
Pommel → Medial Thigh Support
Hip Pad → Lateral Hip Support
Scoliosis Pad → Trunk Support
"H" Harness → Anterior Chest Support

Dimensionality:
Linear and angular dimensions play a significant role when evaluating for a seating system. Without accurate dimensions, functional and postural goals may not be achieved. These critical measurements are important to maintain or improve range of motion, control tone and reflexes and provide postural stability which results in an optimal sitting position.

Example: Medial Thigh Support
- Distance from Centerline
- Overall Height
- Height above Seat
- Overall Length
- Distance in Front of Seat
- Overall Width
- Angulation

Dimensionality terminology can be developed to describe all support surfaces.

Characteristics:
Characteristics include shape, density, adjustability and removeability.

Shape: Describes surface form
- Flat
- Concave/Convex
- Round
- Contoured

Density: Describes properties of surfaces
- Firmness of understructure
- Properties of foam
- Upholstery covering

Adjustability: Describes ability to modify placement of surfaces
- Changes for growth
- Changes for physical condition

Removeability: Describes the ability to move the surfaces
- Fixed in place
- Removeable
- Swing away
- Flip down

Example: Right Medial Thigh Support
- Properties of foam
  - (types/firmness)
- Properties of upholstery
- Adjustability for change
  - (medially/laterally)
- Fixed in place
- Removeable
- Flip down

Example: Trunk Support
- Properties of foam
  - (types/firmness)
- Properties of upholstery
- Flat
- Contoured
- Adjustability for change
  - (superiorly/inferiorly, medially/laterally)
- Fixed in place
- Removeable
- Swing away

DISCUSSION

Following is an abbreviated case study demonstrating the use of a process for determining one seating component. All other problem areas have been previously addressed except for the right hip contracture.

Problem:
The individual has -15° of right hip abduction.

Goal:
Maintain and prevent further deformity of the right hip.
Prevent skin breakdown on the right medial thigh.
Ensure ease of transfers.

Properties of Component:
Anatomical location -
- Right medial thigh

Dimensionality -
- Distance from Centerline - 2" left of center
- Overall Height - 4"
- Height above Seat - 2 1/2"
- Overall Length - 4"
- Distance in Front of Seat - 0"
- Overall Width - 1"
- Angulation - 105° medially from seat edge

Characteristics -
- Shape - Flat
- Density - Metal understructure covered with closed cell foam. 1/2" foam is on contact surface and 1/4" is on other surface. Support is covered with vinyl upholstery.
- Adjustability - Yes, medially and laterally
- Removeability - Removeable

We have now addressed the individual's right hip limitation by using specific uniform terminology.

CONCLUSION

In summary, this paper plays a beginning role in establishing a uniform terminology for seating and positioning. We hope this will encourage understanding and discussion of the benefits of using a common language. By expanding and modifying these concepts an international means of communication regarding seating can be achieved.

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THE ULTIMATE WHEELCHAIR

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INTRODUCTION

The array of lightweight sport wheelchairs has increased drastically within recent years. The innovative design and numerous accessories accompanying each chair dictates the need for a thorough functional assessment of the wheelchair to ensure the successful matching of the consumer and product.

Realistically, the bond between the client and a wheelchair is a lifelong commitment. This paper will attempt to introduce some of the barriers created by the actual design of the wheelchair and how these in turn impact the union between man and machine.

The lightweight wheelchair is a natural alternative to the high energy-consuming standard weight models. The availability of financial assistance for these chairs and apparent versatility have made them a valuable option for a varied population.

The lightweight chairs will be reviewed in general by examining a few of the core component parts, how these particular features negatively impact the user and some possible solutions.

DISCUSSION

Seat Width

The desired seat width can usually be specified to satisfy the requirements of the user within this chair market. However, when physical deformities indicate the need for external postural support, a larger than optimum width chair is required. Often this alteration in width adversly affects the user's ability to efficiently access the wheels. One solution is to reposition the wheel mounting brackets within the frame of the chair to create the effect of an overall narrowing of the chair between 1-2 inches. This minor adjustment may be critical for some clients.

A second option is to camber the wheels. One must remember that this widens the wheel base, a factor which must be considered for those clients with perceptual involvement.

Seat Depth

A delicate relationship exists between the position of the user and the wheel for self-propulsion. When a back support is required to protect spinal deformities such as the kyphosis of a Spina Bifida child or to accommodate bony deformities as in rotational scoliosis, this ratio is disturbed. One simple solution is to utilize the multi-adjustable axle plates available on most models of lightchairs. However, for those clients who are short in stature and request 8" front casters, the multi-adjustable axle becomes an option in name only as the space between the rear and front wheel is uncompromising. A second more involved remedy is to remove the back upholstery and recess the back cushion provided with specially designed hardware. On one particular model of chair, the chair affords the opportunity to move the entire back section along the wheelchair frame to the optimal position.

Footrests

It has already been alluded to that the wheelchair is comprised of a series of delicate ratios between component parts. Another such relationship exists between the seat depth and the position of the footrest. The lightweight chair literature boasts flexibility in prescribing a range of seat depths and this is a welcome option. However, when a shorter seat length is requested in conjunction with an adult seat width, the chair usually appears with footrests positioned too far in front of the seat for the client to reach. Swing away footrests or clamp on style footrests, if they can be positioned close enough to the client, provide possible solutions.

Often, the traditional footrest may be discarded and replaced by a custom fabricated footrest either attached to a seat of some design or a footboard supported by the frame of the wheelchair. Extensions attached to the footrests and extending back have also been utilized in an attempt to provide more therapeutic lower extremity positioning.

It is noted that the above modifications all incur additional costs for the user and make the footrests more difficult to flip up or swing away.

Footrests can play a vital role in a child's ability to transfer in and out of his/her chair independently. For some children, the ability to swing the front riggings completely out of the way is necessary for a forward transfer. Other users may prefer to transfer forward onto the footrest as a step between the floor and seat. Problems that are encountered with the latter style of transfer include foot plates which are too weak and narrow to adequately support the user. Space between footrest brackets is also minimized with some designs of footrests rendering it very difficult to manoever down on to the footrests. The child who wears a parapodium is further restricted by the wide parapodium base and narrow space between the footrests. Often, the solutions to the above concerns are not easily remedied and usually involve a compromise. The forward transfer may need to be discarded and a side transfer utilized. The concerns with the parapodium may indicate prescribing a wider than optimum wheelchair or the necessity for the user to remove the device whenever in the chair.

Armrests

The option of armrest styles are almost as numerous as the chairs themselves. Therefore, careful evaluation of the purpose for the armrest must be made to ensure the correct sytle is prescribed. Height adjustable armrests are a welcome option for the younger growing child but often the mechanism for adjustment and removal are inaccessible to the user, limiting the independence of the individual who must perform side transfers. It has also been observed that in the lowest position of a particular style of adjustable armrests, the client is unable to fasten the brakes.

A swing away style armrest is ideal for some clients but easy access is again a concern. The flip-up style presents an identified problem of the armrest falling down during transferring. For those clients who utilize a forward transfer and push up on the armrest a full length style stable armrest may be considered.

Ease of Folding

The ultimate would be a chair that is never folded and that everyone drives vans. Reality and smaller cars have imposed restrictions on portability. The ability to remove footrests and the option of a quick release axles has significantly improved the weight and compactness of the wheelchair. However, removal of parts is time consuming and undesireable in inclement weather. The solutions to this common problem are not easy to remedy and are influenced by the physical abilities of the user and means of transportation available.

CONCLUSION

The selection of an appropriate wheelchair is an involved process and may be likened in some aspects to purchasing a car. Each chair is unique in its design and careful consideration of all aspects of the product is mandatory to ensure that the match between user and wheelchair fosters independence rather than creating barriers.

SUGGESTED READING

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CANADA

AN EVALUATION POWER WHEELCHAIR SET UP FOR SWITCH ACCESS

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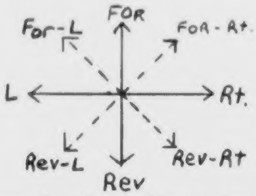
INTRODUCTION

There was a need at the Matheny School to develop an evaluation power wheelchair for clients who can not operate a standard joystick. The chair was designed so that it can be easily changed from one set-up to another for evaluation of different clients. This paper concentrates on the switch access method of control.

METHODS

In order to access all eight available directions directly four switches are needed. When one of the four switches is hit, the forward, reverse, left or right directions are obtained. Combinations yield diagonal directions (i.e. hitting the forward and right switches simultaneously yields the forward-right diagonal direction).



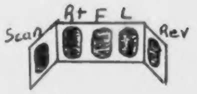
In addition to the four directional switches a fifth, scan switch, is needed. When activated this switch scans through the various modes of the power wheelchair's electronic control unit (ECU). These modes are generally off, on at three speeds, an environmental control mode, and an auxillary mode.

An optional sixth switch for emergency stop was added as a safeguard. The emergency stop switch is not standard on the ECU's available; however it may be necessary for some clients. A normally closed switch was put in line with the power on/off toggle which when hit resets the scan to the off mode.

Head Insert

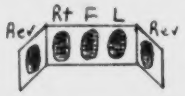
A three panel head insert with adjustable side panels was developed. This provides a variety of head switch arrangements. The head insert can accommodate up to six switches. The most common arrangements are with three and five switches.

Arrangement 1:



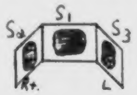
This arrangement allows the operator to activate the five necessary switches with their head. The problem with this set-up is that only 7 of 8 directions can be accessed since the reverse switch is too far away from the right switch making the reverse-right parameter impossible to access.

Arrangement 2:

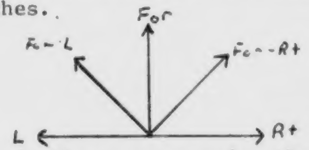


With this arrangement two reverse switches are used to allow head access to all eight directions. This set-up requires the operator to access the scan switch with an alternate part of the body (i.e. knee, elbow).

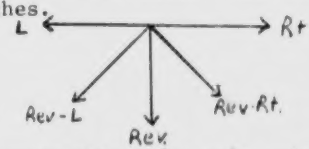
Arrangement 3:



The center switch (S1) in this arrangement is used for both forward and reverse. To change from forward to reverse another switch (S4) (SPDT stationary contact) is needed. When this switch (S4) is hit, switch (S1) will change mode until switch (S4) is hit again. When S1 is in the forward mode, the following directions can be accessed from the three head switches.

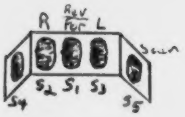


When S1 is in the reverse mode, the following directions can be accessed from the three head switches.



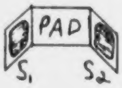
With this arrangement the mode switch (S4) and scan switch must be accessed with alternate parts of the body.

Arrangement 4:



This arrangement provides the same function as the preceding; however the mode switch (S4) and scan switch (S5) have been placed on the head insert. This arrangement is better for the client who can not access switches with other parts of the body. The latter is better for those who can activate switches with other parts of the body and have difficulty with the five head switches.

Arrangement 5:



In this arrangement one of the two switches can be used to scan through the eight available directions. The other switch to activate the chair to move in the selected direction. There are several ways to set up the scan to benefit different operators.

Lapboard
A lapboard was designed with holes in it to accommodate various switches.
Elbow switches can be positioned in the various holes in the armrest portion of the lapboard. These switches can be set up to be activated by pushing down, back or side to side with the elbow.
Knee switches can be positioned on the underside of the lapboard to allow side to side or upward knee activation.
Hand switches can be positioned lying flat or upright on the surface of the lapboard to allow hand activation by pushing down, forward, or side to side.

A small keypad can be positioned on the lapboard for the client who has poor gross motor function of arms but can press light action switches with one or more fingers.

Seating Considerations
The positioning of the wheelchair operator is as important as the positioning of the switches. The operator must be given good postural support wherever needed. For the evaluation power wheelchair the seating must be adjustable to accommodate a variety of clients. Seat depth, seat angle, trunk laterals, hip laterals, and abductor pummel all need to be adjustable. Some clients need chest and/or arm straps to stabilize their upper body. Foot straps may also be required.

DISCUSSION

With the population at Matheny School (primarily cerebral palsied), the head insert proved to be the most valuable part of the system.

Several of our clients who were earlier evaluated for accessing five switches with their hands were always looking down at the switches and not where they were going. To operate the switches in the head insert the operator must keep their head up. To activate the left turn switch the head must be moved to the left, etc. Thus, when activating the switches the operator's head is already facing in the direction the chair will be going in.

Several clients that have been using a headpointer to access a proportional joystick on their lapboard were experiencing neck and/or back pain from leaning over. Access through the head insert encourages better posture for the operator.

The new electronic control units offered by today's power wheelchair manufacturers allow the client to scan into an environmental control mode. This allows the client to operate environmental controls through the same switches that operate the power chair. An electronic augmentative communication device can also be accessed through these same switches.

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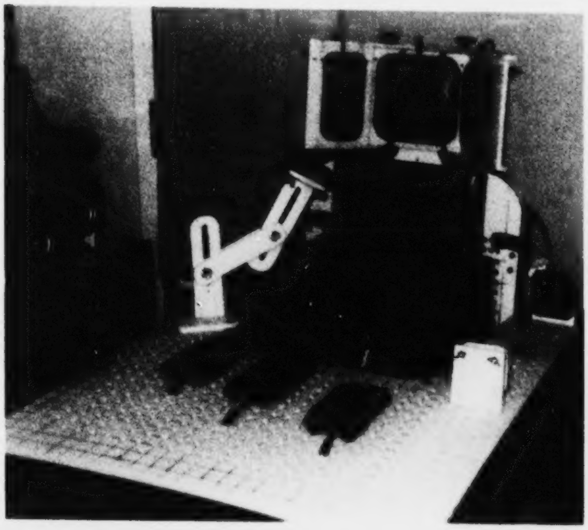


EFFICIENCY COMPARISON OF WHEELCHAIR PROPULSION USING HAND RIMS, LEVER DRIVES AND SKI POLES

L. Quinnan-Wilson, C.J. Hughes, J.J. Chen, C.E. Brubaker

INTRODUCTION

Many factors can affect the efficiency and propulsion of a wheelchair (WC). Generally, these factors can be classified into three categories: (1) forces acting on the WC (2) the physical work capacity (PWC) of the user (3) the interface mechanism linking the chair to the user. Forces acting on the wheelchair would include drag forces related to rolling resistance of the tires and speed of propulsion (aerodynamic drag). User PWC also needs to be considered since this factor influences the magnitude of motive force available to propel the chair not only in terms of speed but also propulsion efficiency. Absolute power outputs can range anywhere between 10.4 W to 125 W for wheelchair non-athletes and athletes respectively (1). Efficiency can also be directly related to the seat orientation of the user in relation to the hub axis (1,2,3,4). Furthermore, work performance and efficiency can be influenced by the type of propulsion interface (1).

It has been reported that standard wheelchair operation at speeds of 2-3 km/hr on a level surface results in an efficiency of 4-6% (1). However, efficiency can be increased to as much as 16-20% by increasing the PWC of the user and modifying the chair by way of moving the wheels forward, lowering the seat, leaning the wheels inward and using smaller grab rims and larger wheels (1). The present study is an evaluation of three propulsion methods relative to speed.

METHODS

Four able-bodied males, aged 23-27 years, gave their informed consent to participate as subjects. The test protocol required each subject to propel a WC about an indoor area, 25X25 meters, using three different propulsion methods: (1) Hand rim (2) Lever drive and (3) Ski pole, at speeds of 2, 4, 6 km/hr. Hand rim propulsion used 24 inch wheels and 20 inch hand rims. This chair was also used for the propulsion with the modified 46 inch ski poles (with handles and a 4-pronged tip at the end to allow traction). The lever drive chair had a lever radius of 18 inches. Details of this type of chair have been described elsewhere (5). These configurations resulted in respective mechanical advantages of .833 and .6 for rim and lever propulsion, respectively. The mechanical advantage for ski pole propulsion varied as a function of limb segment angles and was estimated to range from .4 to .8 during a typical stroke.

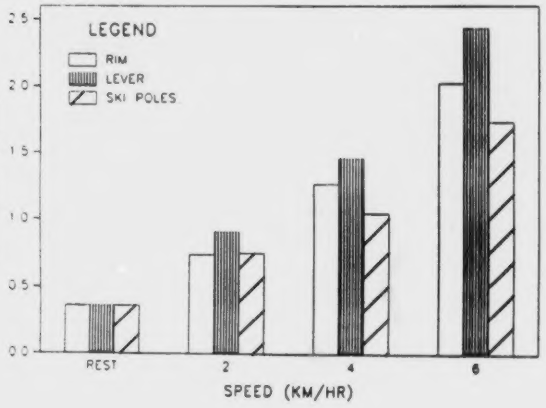
The subjects performed in each WC for 3 minutes at the specified speed which was randomized between subjects. Proper speed was maintained by using a pacer wheel. Speed accuracy was +.20 km/hr. A rest interval of approximately 20 minutes occurred between tests. Oxygen consumption was determined for the rest condition and for the last minute of each exercise test by analyzing expired air collected in a Douglas bag attached to a frame at the back of the WC. Gas analysis was performed using Beckman OM-11 oxygen and LB-2 carbon dioxide analyzers. Drag forces for both WC were calculated by towing the chair on a treadmill at velocities comparable to the test speeds. The mean drag force times the test distance for a given time resulted in determination of the work it took to propel the chair. This value was divided by the mean oxygen consumption minus the mean resting value which was converted to watts. The result yielded an efficiency value for each test condition.

RESULTS

The results of the test protocol in relation to mean oxygen consumption are shown in Figure 1. All WC test conditions showed an increase in oxygen uptake as speed increased. At all speeds, lever propulsion showed the highest oxygen values. In addition, the hand rim condition showed greater oxygen requirements in comparison to the ski poles. Figure 2 shows the mechanical efficiencies in relation to both speed of propulsion and propulsion method.

Figure 1:

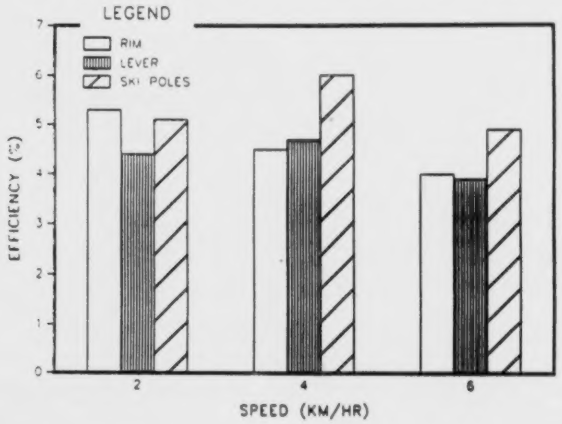
O2 CONSUMPTION AS A FUNCTION OF SPEED FOR 3 MODES OF PROPULSION



Efficiency percentages for the rim condition were 5.3, 4.5 and 4.0%, for 2, 4, and 6 km/hr, respectively. Efficiencies were 5.1, 6.0, and 4.9% for the ski poles and 4.4, 4.7, and 3.9% for the lever condition. An efficiency of 6.1% was obtained at 8 km/hr for ski poles only.

Figure 2:

EFFICIENCY PERCENTAGES FOR 3 MODES OF PROPULSION



DISCUSSION

The results obtained for rim propulsion efficiencies are within the range obtained by numerous investigators for this mode of wheelchair propulsion. In contrast, the values for lever propulsion were considerably below those obtained in previous studies (3). This is more surprising in light of the lower mechanical advantage for lever propulsion., There are several possible explanations. The prototype lever system was not very robust and was difficult to maintain in adjustment resulting in high drag. Drag was also increased by the smaller diameter wheel. A third possibility is the need to provide additional force in an inward direction to engage the clutch. The ski pole propulsion efficiency increased from 2 to 8 km/hr, with an apparently aberrant decrease at 6 km/hr, suggesting that maximum efficiency would likely occur at a yet higher speed. One difficulty associated with testing at the higher speeds was negotiating the turns required by the size of the enclosure.
Further work is needed.

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ACKNOWLEDGEMENT: UVa, REC, P.O. Box 3368, Charlottesville, VA 22903, NIDRR Grant No. G00-83-00072.

STATIC AND DYNAMIC FORWARD STABILITY OF OCCUPIED WHEELCHAIRS: INFLUENCE OF ELEVATED FOOTRESTS AND SIMULATED CASTS

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INTRODUCTION

Elevating wheelchair footrests are used by patients who have recently had surgery on their legs, by those who are wearing plaster casts for fractures and by patients who are unable to flex their knees. In this study we test the hypothesis that elevating the footrests reduces the static and dynamic forward stability of occupied wheelchairs and that simulated plaster casts on the legs further reduce stability.

METHODS

We studied 20 normal adult subjects with their informed consent. Two wheelchairs were used--one was a reclining Theradyne chair and the second was an Everest and Jennings wheelchair with a conventional rear axle position. Simulated casts consisted of fabric thigh and calf sections which held metal bars in place, based upon study of 10 dry full length leg casts after their removal from patients.

Static stability testing was performed using a tilting platform (1). The platform was slowly raised until both rear tires abruptly lifted from the platform. The angle of the platform from the horizontal was recorded using a pendular goniometer. Each subject was assessed in both chairs, with both footrests in the lowered position, with each leg elevated to 90° (with and without a simulated cast) and with both legs elevated (with and without simulated casts). A balanced ordering of conditions was used.

Dynamic testing was performed by having subjects descend a 17° ramp, the wheelchair having been released from a position where the casters were 56 cm from the end of the incline. Each trial was analyzed by slow motion videotape qualitatively and using a 3-point nominal scale ("no tip", "transient tip", and "full tip").

The dynamic testing was carried out, in balanced order, only in the conventional chair, with the footrests both lowered or both elevated, in the latter case with and without simulated casts.

RESULTS

The static stability data for each of the conditions and chairs are shown in Table 1.

The results of the dynamic testing are illustrated in Figure 1. With both footrests in the lowered position, the rear wheels of only 7 subjects lifted from the surface, and then only temporarily. The extent of this tip was 5.4 (± 2.5)°. With both footrests in the elevated position, all 20 trials resulted in rear wheel lift, 8 transiently. The extent of the transient tip was 12.2 (± 1.9)° The other 12 subjects continued to tip until the footrests hit the floor; the extent of the tip was 35.9 (± 3.2)°. When both footrests were elevated and the subjects wore simulated casts, all 20 tipped fully, the extent of the tip being 36.8 (± 3.0)°.

DISCUSSION

There are a number of implications of this study. The reclining wheelchair was significantly more stable, and although it has a greater turning circle and is heavier than the conventional chair, its prescription should be considered whenever both legrests require elevation. Optional forward stabilizers should probably be used whenever even a single footrest is elevated or removed. Our results also underline the importance of realistic testing of wheelchairs occupied by their intended users.

The limitations of this study include the use of a qualitative rather than a kinetic analysis of dynamic stability and the use of able-bodied subjects rather than patients whose body morphology may affect wheelchair stability. The results on two wheelchairs and a single ramp angle should only be generalized with caution to other wheelchairs and settings. Nevertheless, we feel confident in concluding that elevating the footrests significantly reduces the static and dynamic forward stability of occupied wheelchairs, and that the addition of simulated casts further reduces stability.

ACKNOWLEDGEMENTS

We thank the Nova Scotia Rehabilitation Centre, and Mrs. E.C. Gregory. This study was supported by a grant from the Canadian Paraplegic Association.

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Dalhousie University, Halifax, Nova Scotia,
Canada. B3H 4H7.

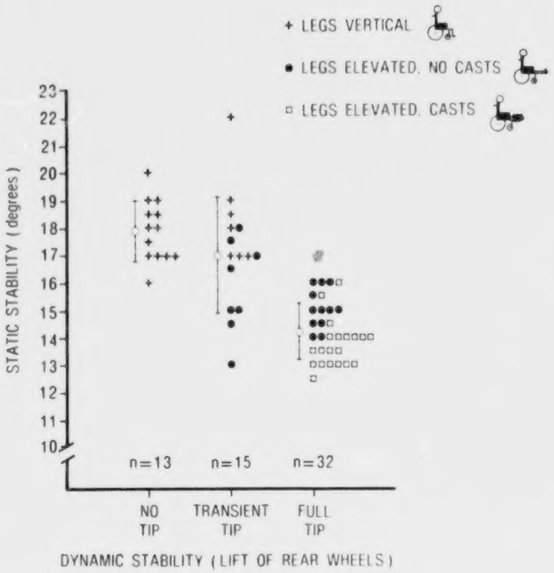

Fig. 1. Dynamic and static (mean ± 1 SD) wheelchair stability.

Table 1. Static forward stability for conventional and reclining wheelchairs occupied by normal subjects (n = 20)

	Static Stability[1]	Mean Difference in Stability[2]			
	Mean ± 1 SD	One leg up, no cast	One leg up, cast	Both legs up, no casts	Both legs up, casts
Conventional Wheelchair					
Legs vertical	18.0 ± 1.4	1.7 ± 0.8†	2.6 ± 0.9†	2.7 ± 1.0†	4.3 ± 1.0†
One leg up, no cast	16.4 ± 1.1		0.9 ± 0.4†	1.0 ± 0.8†	2.6 ± 0.6†
One leg up, cast	15.5 ± 0.9			0.1 ± 0.8	1.8 ± 0.5†
Both legs up, no casts	15.4 ± 1.2				1.6 ± 0.7†
Both legs up, casts	13.7 ± 0.9				
Reclining Wheelchair					
Legs vertical	21.8 ± 1.4	1.9 ± 0.9†	2.7 ± 0.9†	3.2 ± 1.1†	4.9 ± 1.2†
One leg up, no cast	19.2 ± 1.2		0.8 ± 0.4†	1.4 ± 0.9†	3.0 ± 0.7†
One leg up, cast	19.1 ± 1.0			0.6 ± 0.9*	2.2 ± 0.6†
Both legs up, no casts	18.6 ± 1.2				1.7 ± 0.8†
Both legs up, casts	16.9 ± 1.2				

[1] Static stability, in derees, is the angle of the tilting platform at which the rear wheels lift from the platform.

[2] Mean difference, in degrees, from matched-pairs t-tests; degree of significance: $* = p < 0.01$, $\dagger = p < 0.001$.

A DESIGN FOR AN ADJUSTABLE ANGLE-IN- SPACE SEATING SYSTEM FOR A MANUAL RECLINING WHEELCHAIR

Rehabilitation Technology Center-Indianapolis
Ray Rego, Rehabilitation Engineer

INTRODUCTION

This presentation addresses the issue of maintaining the seat to back angle of a wheelchair seating system while having the option of adjusting the tilt of the seating system to various angles. The system described is for installation in an Everest and Jennings full reclining wheelchair with a #49 "EZCline" back. The advantages of the system are as follows:

1. It allows the use of a standard reclining wheelchair as a mobility base for an angle-in-space seating system.
2. It allows the wheelchair to be folded for transport.
3. The system mounts to chair without drilling or other modifications to chair frame.
4. By using a forward pivot point client is kept low when put in angle. The center of gravity is also kept low for safe transit.

METHOD

A frame is made that connects the back and seat cushions together. Attached to the frame are the components for angle-in-space, and footrests. The frame is designed so that the seat and back cushions can be disassembled if necessary for transit.

Two pivot sockets are attached to the bottom of the seat cushion frame indexes into the sockets. Two contour-cut nylon wheels are attached to the back cushion frame and are designed to roll along the push handle tubes.

Once the seating system is installed on the wheelchair, the angle of tilt can be changed by using the recline mechanism of the wheelchair. As the push handles are lowered, the nylon rollers of the seating system start a decending arc, tilting the seating system. The degree of tilt is adjustable.

The limitations of the system are as follows:

1. The seating system must be able to drop through the seat rails. This requires a mobility base which is at least two inches wider than the seating system.
2. The angle of recline is limited by the cross frame.

CONCLUSIONS

Once installed on the chair, the angle-in-space seating system works with surprising smoothness and very little effort due to the leverage of the push handles and the use of rollers made of self lubricating nylon. The system has worked safely and effortlessly and allows the installation of a custom seating system, incorporating angle-in-space in a commercially available mobility base.

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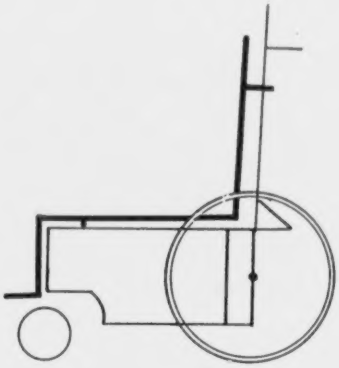
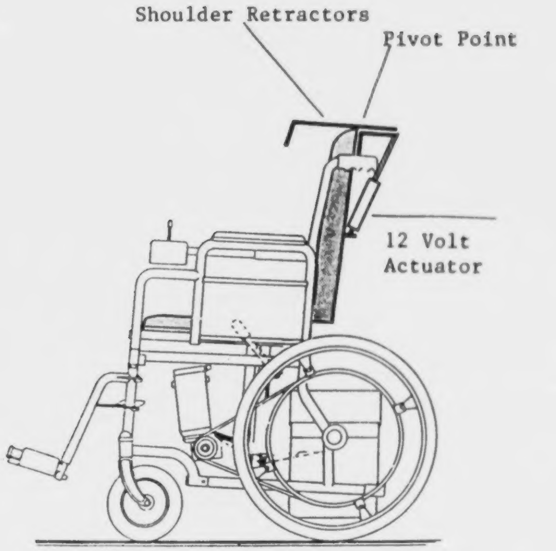
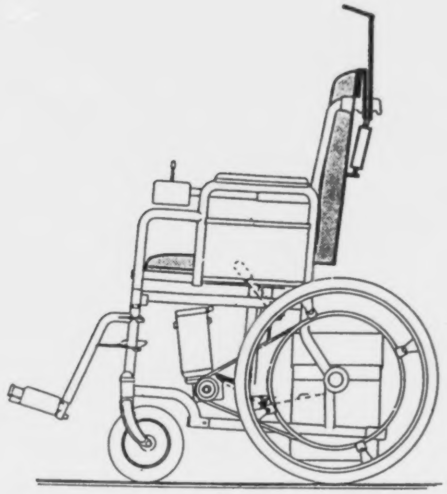


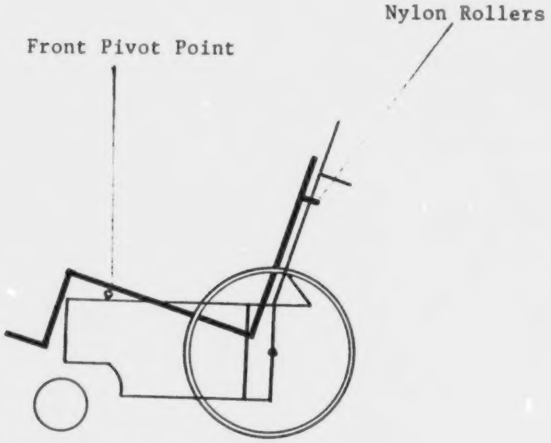
Seating System at 90°-90°-90°


Shoulder Retractors
Pivot Point
12 Volt Actuator

Power Shoulder Retractors in Down Position



Power Shoulder Retractors in Up Position


Front Pivot Point
Nylon Rollers

Angle in space by reclining.

A New Technique for Custom Contoured Body Supports

T.F. McGovern, S.I. Reger, E.N. Snyder, B.L. Sauer

Department of Musculoskeletal Research
The Cleveland Clinic Foundation

INTRODUCTION

Proper seating and positioning for the disabled child and adult is often dependent upon a contoured body support. Several methods exist for the measurement, fabrication, and fitting of these supports(1). The dilation molding technique offers the positioning team a controlled environment to form and simulate contoured systems. Control over the fit of the final system is lost if the clinical team cannot make adjustments before delivery. The purpose of this project was to develop an effective method for fitting and fabrication of contoured seating systems. The carved foam on plywood method has been modified to provide a new method of body support fabrication and fitting. Computer aided technology has been developed and applied to this new fabrication technique. Positioning is the primary focus of the Rehabilitation Engineering Clinic within the Department of Musculoskeletal Research at the Cleveland Clinic Foundation. Within a twelve month period the clinic team evaluated 106 clients. The fabrication technique described below provides the contoured support for fitting within two weeks of the molding visit.

METHODS

Following a complete seating evaluation, with the conclusion that a contoured support is appropriate, the client is asked to return for a molding visit. The desired posture is reproduced and supported using a modified dilation molding frame (Pindot Products, Chicago, IL) (Fig. 1). The complete mold is cast in one piece (Fig. 2). Casting in one piece preserves the exact seat to back orientation. When dry, the casts' orientation in space is measured and recorded relative to the molding frame. A vertical midline is also placed on the cast.

A manual cast measuring contour gage has been developed (Fig. 3). The gage, 21" wide, is made from 168 parallel 1/8" diameter x 12" long stainless steel rods sandwiched between two foam-lined aluminum channels. The rods can move independent of each other. The gage moves freely horizontally or vertically between two 3/4" diameter pipe guides.

The cast is positioned between the pipe guides maintaining orientation relative to the molding frame. The measuring system is adjusted according to the maximum depth of the cast. 1" and 1/2" thick 8" X 16" ethafoam blanks are prepared and stored for contour transfer and reproduction. The contour gage is moved along the cast midline of the seat and back sections in one or half inch intervals depending on the slope of the cast in the measurement region. At each interval the gage rods are moved toward the cast. The rod ends are positioned to contact a 1/2" to 1" flexible spacer placed on the cast. This allows room for the foam liner used on the final support. The contour gage is then removed from the guides and squarely placed on an ethafoam blank using the gage and the blank midline for registration. The position of the rod ends, reproducing the contour of the cast, are traced onto the ethafoam. This procedure is repeated until the entire cast is represented sectionally on the ethafoam blanks. The blanks are numbered sequentially from proximal to distal.

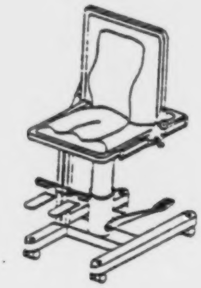


Fig. 1. Modified molding frame.

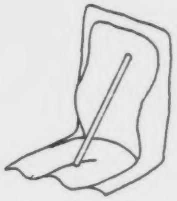


Fig. 2. One piece cast.

The client returns for a fitting evaluation and assessment prior to seat installation into a mobility device. The system can be modified during this visit to most closely match the expectations of the evaluators and the client. When a satisfactory fit is obtained, the system is disassembled and reassembled with foam glue between all sections of ethafoam. A plywood or ABS plastic container refabricated to support the seating system and interfacing hardware. Following installation into the mobility device, the complete system is delivered to the client for trial use with the temporary cover. After a trial period of approximately one month, a follow-up visit is scheduled for final modifications, and vinyl upholstery is formed if desired.

The ethafoam blanks are cut along the contour line using a band saw. The cut ethafoam pieces are assembled according to their midline number and held together with three lengths of threaded rods piercing through the sections (Fig. 4). Plywood caps the ends of the seat and back with nuts on the threaded rods compressing the ethafoam sections between the wood. After smoothing ethafoam edges with a rotating wire brush a 1/2" to 1" polyurethane foam lining is placed into the support. The cast is used to align the seat and back sections. The entire support system is temporarily covered using thin loosely fitting rip-stop material and made ready for fitting.

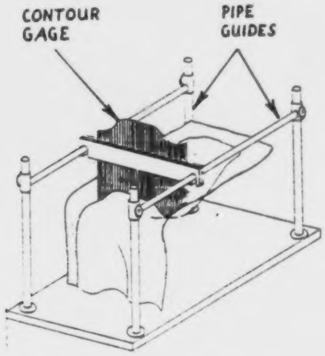


Fig. 3. Cast measureing system.

RESULTS

Seven support systems fabricated using this technique are currently in use. Five additional supports are being prepared. Five clients were diagnosed as cerebral palsy and two were undiagnosed neural disorder. Temporary covers remain on four of the systems in use due to growth or significant postural changes resulting from therapeutic or surgical intervention. The temporary cover provides easy access to the support foams for further contour modification or pressure relief.

An electronic contour measuring gage has been developed to replace the manual gage now used. The electronic device uses 32 linear potentiometers placed side by side. Aluminum arrow shafts linked to the potentiometers are displaced to follow the cast contour and provide 1/2" resolution. Data collection, storage, and plotting is controlled by an IBM PC/AT.

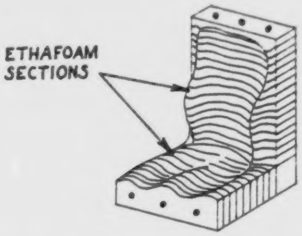


Fig. 4. Assembled body support.

CONCLUSION

The technique described is an efficient means to fabricate contoured body supports. The clinic team maintains control over the fit throughout the process. Needed modifications are often discovered during the one month trial period. The evaluators using this system have found it to be most beneficial for the growing child and the client with postural changes resulting from therapy.

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ACKNOWLEDGEMENT

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THE *SPIRAL* PRESSURE MONITOR

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INTRODUCTION

In order to choose and fit seating and positioning components for immobilized individuals the rehabilitation specialist needs measurement tools to evaluate the skin surface pressures produced by different device configurations. Quantitative measurements are especially useful for evaluating clients with loss of sensation. The *SPIRAL* Pressure Monitor is a device designed to gather information about the distribution of skin surface pressures at a load-bearing interface. It has been used clinically for seating evaluation [1] and in research aimed at studying changes in pressure distribution over time [2,3].

MATERIALS and METHODS

The *SPIRAL* Pressure Monitor consists of three parts: The sensor pad, the electronic interface and control software.

TIPE Pad: The sensor array used is the Texas Interface Pressure Evaluator pad[a]. This commercially available device consists of separate top and bottom sheets of translucent flexible plastic bonded together around the outside edge. It is also quilted together across the face to form 144 small interconnected air chambers. These chambers are arranged in a square 12 x 12 matrix and lie at 1.25" intervals. The pad is air-tight and can be inflated to a desired pressure through an attached hose. Twelve thin electrically conductive strips are bonded to the inside surface of each face. Strips on one face run horizontally to form rows and the those on the other face run vertically to form columns. A row crosses over a column at the center of each air chamber. A small rectangle of resistive material is arranged at the intersection so that an electrical "switch" connection through this material is formed between the row and column whenever the top and bottom surfaces make physical contact. A given switch closes when the externally applied pressure exceeds the constant internal pressure of the pad at that point.

SPIRAL Interface: The interface is a circuit board designed to plug into a bus slot in any IBM PC or PC-compatible computer. It is a simpler, faster version of an earlier stand-alone interface [4] and functions under the control of the host PC to allow the computer to read information from the TIPE pad. The board has two distinct circuits. One circuit is designed to test the state of individual pad switches. The other circuit reads the internal air pressure of the pad. The board is connected to the pad by a cable assembly which has one 24-conductor electrical cable for row and column connections and a plastic air tube to bring pad pressure to the board. Pressure within the pad is raised and lowered with an inflator bulb of the type normally used to control a blood pressure cuff.

SPIRAL Software: The *SPIRAL* software continuously updates the computer's video display during the recording process. This display includes parameter information (pad pressure, data file name, trial number, etc.) and a 12 x 12 array of 1/4" squares which represent pad switch status. An individual square shows bright red when the pad switch is closed and faint blue when it is open. As these squares flicker on and off they provide direct visual feedback as to the state of the pad and indicate whether interface pressures are above or below pad inflation pressure within each switch chamber.

Various programs have been written to control the interface. The primary clinical software for the *SPIRAL* Monitor generates a two-dimensional seating pressure distribution map (Figure 1) which helps identify areas of excessive seating pressure and quantifies the effect of any configurational changes. This is accomplished by first inflating the pad until all switches are opened. Recording then begins as pad pressure is slowly lowered. Each switch remains open until the decreasing internal pad pressure reaches the external pressure and it closes. The pressure at which each switch first closes is recorded and when pad pressure reaches 0 a map of the "first-close" pressures is displayed. The software allows averaging of several such pressure distribution maps in order to minimize the effects of erroneous measurements.

SEATING PRESSURE DISTRIBUTION MAP
(mm Hg)

Back

					7		29				
					1	22		5		2	4
				1				4	2		
			2			22	2	18	19		1
			30	16			3	40	15	3	2
		6	27				4	73	36		
			16	28	27		60	89		3	25
	25		8	44	38		23			3	32
	39			14	54	11		41		25	10
	10		4	1	2		14	7			

Front

Figure 1: Sample Pressure Distribution Map

Additional software records switch openings and closings over periods ranging from seconds to hours. In this application the number and locations of switch transitions are recorded for a fixed pad pressure as opposed to the measurement of absolute pressures described above.

THEORY OF OPERATION

On the *SPIRAL* board are 24 single pole, double throw (SPDT) analog electronic switches. The common terminal of each switch is connected to one column or row of the TIPE Pad. The main computer can control each of these switches. They are arranged so that individual pad rows may be connected either to the positive supply voltage (V+) or to ground (GND). Similarly, pad columns may be connected either to a comparator circuit or to GND. In the comparator circuit the voltage from the column being tested is compared to a constant reference voltage. The output of this stage is a digital signal to the computer indicating that the pad switch is open or closed.

The computer begins the process of reading a specific pad switch by setting the SPDT switches so that all other rows and columns are connected to GND. Next the row under test is connected to V+ and the column under test is connected to the voltage comparator circuit. If the pad switch through the resistive material at the intersection of the active row and column is closed the row voltage (V+) will cause the column voltage to rise. If the pad switch is open the column voltage will remain at or near GND.

The *SPIRAL* board also has a circuit to read the air pressure inside the TIPE pad. The pneumatic tube from the pad enters the rear of the computer and is connected to a solid state pressure transducer which produces an output voltage proportional to the pad pressure. This voltage passes through a simple amplifier to an analog-to-digital converter. The output of this integrated circuit is an 8-bit binary number representing the pad pressure.

DISCUSSION

The *SPIRAL* Pressure Monitor has proven to be a useful measurement tool. It takes less than a minute to generate a pressure distribution map. In the clinical setting this allows different seating cushions to be evaluated quickly. The Monitor is also used during custom cushion molding to help identify and relieve high pressure areas [1]. Most techniques aimed at preventing skin breakdown and pressure sores rely on changing skin pressure distribution in some way. The *SPIRAL* Monitor can be used to study changes in pressure distribution over time or those produced by various interventions such as electrical muscle stimulation [2,3].

In using this system several caveats apply. The ideal situation for maximum accuracy would be to use the TIPE pad on a flat, hard base rather than a soft, contoured cushion. Obviously this would defeat its usefulness but it points out that the more highly contoured the seating surface is the less accurate the measurements will be. In some instances the pad may be pinched or creased so that switches at these locations will not read pressure properly. The operator must be aware of this effect and interpret recorded results accordingly.

The TIPE pad (and as a result the *SPIRAL* Monitor) has inherent error in measuring *absolute* pressure [5]. In a typical application the cushion, the pad and the person being measured form a complex system where observed *absolute* pad pressure may be affected by factors such as cushion elasticity and seat shape. Nevertheless the pad gives more accurate information about *relative* interface pressures and is good at measuring changes in pressure distribution.

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CUSTOM MOLDING OF SEATING AND POSITIONING COMPONENTS USING THE *SPIRAL* PRESSURE MONITOR

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INTRODUCTION

Contoured seating and positioning components are frequently used to accommodate musculoskeletal deformities and improve pressure distribution for handicapped individuals. The *SPIRAL* Pressure Monitor (1) is being used during molding of contoured components to achieve improved pressure distribution and fit.

METHODS

Materials

SPIRAL Pressure Monitor: The *SPIRAL* Pressure Monitor is a combination of hardware and software which allows an IBM PC compatible computer to be used to produce a two-dimensional map of the surface interface pressures. The system is composed of a plug-in circuit board for the computer, a combination electrical-pneumatic cable assembly to connect the computer to a Texas Interface Pressure Evaluator (TIPE) pad[a], an inflation bulb assembly to pressurize the pad, and computer software.

TIPE pressure pad: This is an inflatable pad with 144 pressure sensitive switches arranged in a 12 x 12 matrix. Switches are located within inter-connecting cells (1.25 inches square) formed from two pieces of vinyl plastic bonded together. The pad can be inflated to any desired pressure from 0 to 110 mm Hg. Switch closure occurs when the externally applied pressure exceeds the internal pressure of the pad. At any moment in time, the open and closed switches represent cells with interface pressures below and above pad inflation pressure, respectively.

The *SPIRAL* system can be used in two ways: 1) A switch status map is displayed on the computer screen by a pattern of open and closed switches, depicting those areas which are below and above the pad inflation pressure. 2) A pressure distribution map is generated by recording the inflation pressure at which each switch closes while air is slowly leaked from a fully inflated pad. The program used to generate the pressure distribution map allows for several maps to be averaged together to create a more accurate mapping.

Contour-U Molding Frame: The Contour-U Molding Frame[b] is a multi-adjustable unit incorporating vacuum consolidation techniques to produce molds for seat and back cushions. The Contour-U valve system has been modified by the addition of bleed-in valves with regulators designed to permit independent, fine control of seat and back vacuum. This valve system modification more easily allows slight changes to be made in the shape of the seat or back mold, which in turn can affect the pressure distribution of the seating system.

Protocol

An initial contour is molded with the patient positioned in the molding frame. The *SPIRAL* system is set up with the TIPE pad on the mold and the client repositioned as before. In order to modify the mold, vacuum is slightly reduced to soften it. Patients may or may not need to be removed from the molding frame depending on the type of modifications being made. The changes can be dynamically monitored by observing the switch status map on the computer screen at an appropriate pad inflation pressure. Intermediate molds should be checked by generating a pressure distribution map. This process can be repeated until an optimal contour is produced.

The use of the pad is somewhat limited as folds may be present in the TIPE pad at highly contoured areas such as hip blocks or abduction pommels. These folds are inevitable but generally occur in areas where pressure readings are less critical. (The erroneously high pressure readings in the bottom left corner of figure 2a represent an example of this problem).

CASE STUDIES

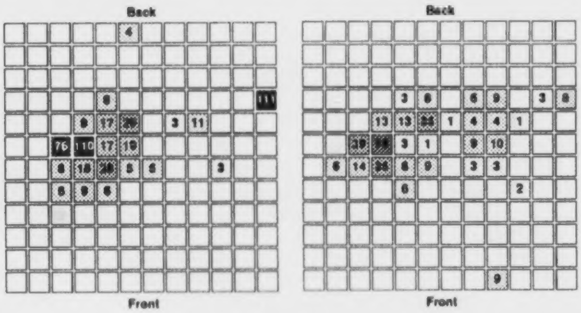
Case #1

S.B. is a 10 year old cerebral palsied female child with increased flexor tone and a severe pelvic obliquity. Figure 1a shows a pressure distribution map generated after the patient's seat mold was formed to the initial desired shape. The map shows the majority of weight being born on the right ischial tuberosity, with surrounding pressure levels being very high. Figure 1b shows a pressure distribution map generated from the same seat mold after modifications were made to improve pressure characteristics. The map shows levels in the area of the right ischial tuberosity to be much lower than before, with an increase in the weight born on the left ischial tuberosity, indicating improved pressure distribution.

Case #2

M.T. is a 36 year old male with paraplegia since age 13. Due to severe recurring problems with decubitus ulcers extending from the right ischial tuberosity to the mid thigh, the right leg was amputated above knee and the calf tissue used to construct a flap. The flap, located on the underside of the right hip, is 8" long, 4" wide, and 3" thick. Problems encountered by the patient due to the presence of the flap include poor balance to the left side, internal rotation of the right hip, and loss of circulation to the flap area due to tissue distortion. A custom seat cushion was molded to accommodate for the thickness of the skin flap, decrease internal rotation of the right hip, improve sitting balance, and minimize tissue distortion.

Figure 2a shows a pressure map generated with the patient's seat mold formed to the initial desired shape. The map shows extremely high pressure levels in the area of both ischial tuberosities, the sacrum, and in the area of the skin flap on the right hip. The mold was modified until an optimal contour was achieved. It was then decided that a gell pad[c] should be used over the seat mold to further improve pressure distribution and reduce tissue distortion. The resulting pressure map is shown in Figure 2b. The map shows levels in the area of both ischial tuberosities, the sacrum, and the skin flap on the right hip to be considerably lower than before, with significant improvement in overall pressure distribution throughout the seat mold.



a b

Figure 1: Pressure Distribution Maps from Case #1

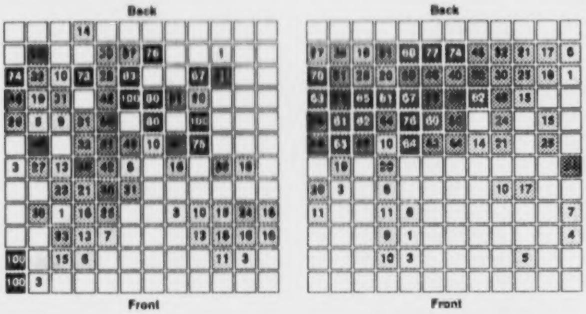


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Figure 2: Pressure Distribution Maps from Case #2

CONCLUSION

The *SPIRAL* system, used to evaluate and modify custom molded seat and back cushions during the molding process, has been found to be a very effective technique. Case studies presented show that peak interface pressures can be reduced and pressure distribution markedly improved. The *SPIRAL* system also has application for comparing alternative components such as different modular seating cushions. Other seating clinics have documented the value of doing interface pressure evaluations for prescribing wheelchair cushions for all of their patients (2). The results achieved warrant the use of pressure distribution measurements in many evaluations of custom molded and modular seating/positioning components.

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SUPPLIERS

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DESIGN OF A COMPUTER AIDED MANUFACTURING SYSTEM FOR CUSTOM CONTOURED WHEELCHAIR CUSHIONS

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INTRODUCTION

Recent research at the University of Virginia Rehabilitation Engineering Center has indicated that substantial reductions in pressure at the body-cushion interface can be realized with custom contoured wheelchair support cushions.[1] A computer aided manufacturing system which has the capability to quickly and accurately cut contoured cushions has been developed. The system, in conjunction with the IAFPS,[2] is to be used as a research tool in the Seating Clinic to study the effects of custom contoured cushions. The system consists of a microcomputer, computer numeric controller (CNC), and three axis milling machine.

METHODS

The cutting system which has been designed and built is a programmable three axis servo drive position and velocity feedback control system. Digital contour data is first transmitted from the data acquisition system[2] to a microcomputer via an RS232C serial interface. The data is processed by the microcomputer and a CNC program is formed. The CNC program is then downloaded to the CNC over the same RS232C communications port. The CNC in turn executes the program.

As seen in Fig. 1, the CNC receives only position feedback. Velocity feedback is used in an internal amplifier feedback loop. The CNC output is a voltage corresponding to a desired angular velocity of the drive. The CNC feedback is relative positional information taken off the motor shafts by incremental optical encoders. Velocity feedback comes from tachometers coupled to the motor shafts. The velocity feedback is subtracted from the CNC velocity command to give a velocity error signal. This velocity error signal is pulse width modulated and amplified to drive the servo motors.

In addition to acting as a host to the CNC, the microcomputer serves as a user friendly operator interface. All data transfers and processing can be initiated by an operator from a menu driven calling program run on the microcomputer. The major functions of this calling program are reading and writing contour data files and reading, writing, forming, and transferring CNC programs.

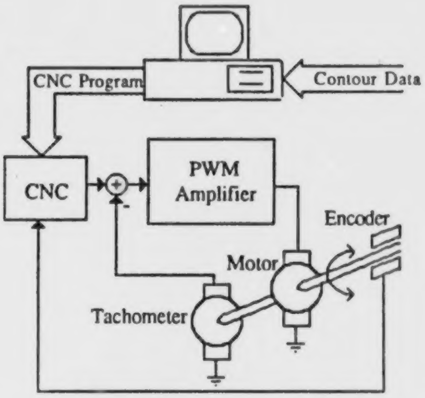

Figure 1 - Block Diagram of Cutting System (One of Three Axis Shown)

The goal of the manufacturing process is to cut a smooth, accurate contour in a minimum amount of time. Unfortunately, cutting a smooth contour necessitates cutting in small increments which naturally takes more time. This trade off makes the selection of a cutting tool and indexing increment very important. A large tool will require fewer indexing steps and, hence, less time than a smaller tool. However, the size of the cutting tool is proportional to the accuracy of the resulting contour. Figure 2 is a simulation of cutting patterns generated by different size tools. As seen in the figure, the surface cut by a 1/2 in. diameter tool and 1/2 in. indexing increment is considerably more accurate than the surface cut with a 1 in. diameter tool and 1 in. indexing increment. A tool radius of 1 in. and an indexing increment of a 1/2 in. was determined to produce a satisfactory surface in a reasonable amount of time.

This 1/2 in. resolution requires that the 8x8 array of 64 data samples from the contour gauge[2] be interpolated. This is carried out using a Whittaker reconstruction procedure to form a 33x33 array of contour data points. The result is the desired 1/2 in. resolution over the 17x17 sq. in. surface area of the cushion. In addition to the data interpolation done prior to forming a CNC program, during program execution, the CNC linearly interpolates between programmed points. This provides a means of producing a smooth, continuous surface as opposed to the jagged surface which would result from an uncontrolled point-to-point cutting scheme. This continuous path control is an essential function in the manufacturing of a contoured surface.

Two other design considerations concerning the tool selection are the type of tool and spindle speed. A spherical wire brush was found to be capable of cutting all available varieties of foam at a relatively low spindle speed (4200 rpm.). Other types of tools which were used included double edged flat blades, router bits, and an elongated solid spherical cutter. The flat blades and router bits required a much greater spindle speed to cut at the desired rate and the elongated spherical cutter was considerably more expensive.

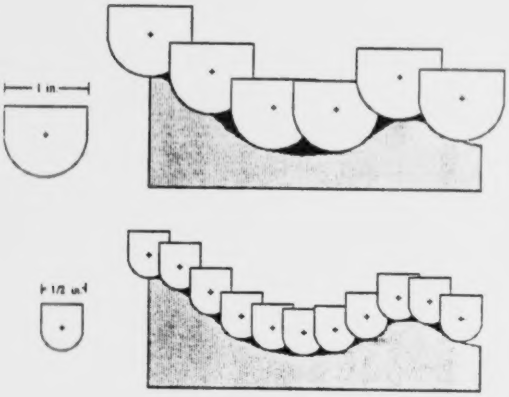

Figure 2 - Simulation of Cutting Pattern Generated by Different Size Tools (Cross Sectional View)

RESULTS

The cutting system has been built, tested, and implemented. The types of foam cushions which have been cut include various ILD of medium and high density polyurethane foam, ethafoam, and viscoelastic foam. Figure 3 is a photograph of a typical contoured polyurethane foam cushion.

Combined with the IAFPS, the computer aided manufacturing system can provide a cost-effective method for manufacturing custom contoured cushions. The total time required for patient evaluation, contour measurement, and cushion fabrication is estimated to be one hour. (The time required to cut a cushion is approximately 20 minutes.) The cost involved in repeated cutting is the cost of raw materials (*ie.* the foam cushion) which is about $4.00.

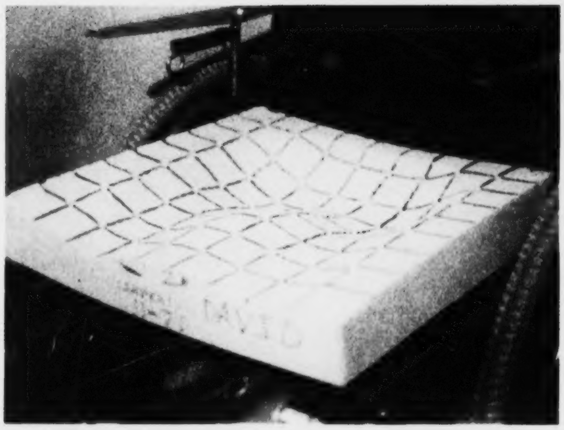

Figure 3 - Photograph of contoured polyurethane foam cushion

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ACKNOWLEDGMENTS

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EFFECT OF CONTOURED SUPPORT SURFACE ON PRESSURE DISTRIBUTION

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INTRODUCTION

Pressure loading and tissue distortion are the two crucial factors in tissue survival in W/C seating. Support surface and cushion material play an important role in determining the load transfer at the body-cushion interface and the soft tissue deformation. According to Hertz contact theory, the pressure relief for tissue can be optimized by matching support contact surface and cushion property to body contour and tissue compliance. The application of this theory is complicated by the complexity of biomaterial behavior of tissue and cushion, and the measuring of unloaded buttocks contour on seated persons in the gravity environment.

This study was designed to examine contour - pressure relationship on typical foam cushions. To closer approximate the unloaded buttocks contour, two or more iterations of the contour recording and cutting process were applied.

METHODS

Six normal subjects were included in the study, 3 male and 3 female(Table 1). Four polyurethane foams with different density and ILD were used – HR-70, HR-55, HR-45 and D-71(Table 2). An Instrumented Adjustable Fitting and Positioning Seat(IAFPS) was used for body positioning and contour measuring[1]. An automated CAM system [2] was designed and interfaced with the IAFPS to fabricate custom contoured cushions.

For each subject the seat was adjusted to a 5^0 angle to the horizontal, and the back to a 100^0 angle. For each foam, seat contour measurement was made by recording cushion deflection with 64 potentiometers arranged in a 16"X16" area. The contour data was sent to an LSI-11 computer where it was expanded from the 8X8 array to a 33X33 array using Whittaker's Reconstruction interpolation method. The data was transferred to CAM milling machine for custom contouring. Pressure measurement was made with an Oxford Pressure Monitor. The pressure at 24 points arranged in a 4 1/2" X 8 1/2" rectangle was recorded for analysis. The transducer was centrally placed in the regions of the ischial tuberosities. Cushion deflection and pressure data was first recorded at the body-cushion interface for each flat foam. The cushion was then cut using the measured deflection. Deflection and pressure measurements were again taken and the cushion was recut. This procedure was repeated until the cushion was bottoming out under the load of the subject.

Table 1: SUBJECT DATA

SUBJECT NUMBER	SEX	AGE	WEIGHT (lbs)	HEIGHT (cm)
N1	F	32	150	170
N2	F	22	130	163
N3	F	26	122	162
N4	M	37	187	176
N5	M	23	151	171
N6	M	28	172	188

Table 2: CUSHIONS USED IN THE STUDY
Dimension(inch): 16X16X3

Foams	ILD*	Density	Company
HR-70	69-79	3.25	Luxaire
HR-55	51-59	2.8	Luxaire
HR-45	40-50	2.85	Luxaire
D-71	50-55	4.8	E.P. Carpenter

* ILD on 4" thickness at 25% deflection.

RESULTS

The contoured seat surfaces developed on these four foams for the normal subjects were similar to each other, but had different contour depth and sizes. A typical custom contoured cushion with a double symmetric contour at the two buttocks is shown in Fig. 1. For each subject, the HR-45 had the most contour depth followed by the D-71, the HR-55 and HR-70. An example of contour development over successive iteration process is shown in Fig. 2. Each subject showed similar results on the four forms; a large cushion deflection on the flat foams was followed by lesser deflections over each iteration. In general, the max. cushion deflections for the third iteration contours measured less than 5 mm.

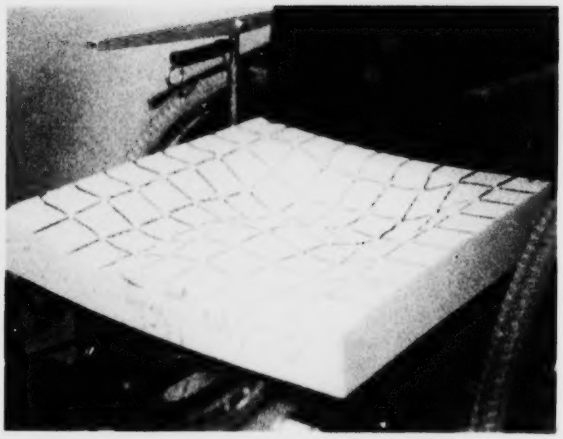

Figure 1: Contoured polyurethane foam cushion

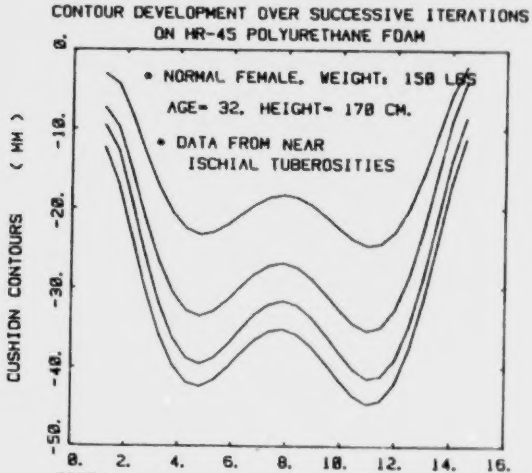

Figure 2.

The peak pressure measured at the buttocks-cushion interface is shown in Figure 3. The peak pressure is significantly reduced with the contoured support surfaces developed in this iteration process. The results indicate that the contoured HR-45 cushions have the lowest pressure peaks, followed by the D-71, the HR-55 and HR-70 cushions. However, the HR-45 foam bottomed out after the 2nd iteration contour, and the D-71 foam after the third iteration contour for all male subjects. Subjects with thicker buttock tissue were found to have lower peak pressures and a more uniform pressure distribution. The mean and standard deviations of the pressure profiles followed the same trend as the peak pressures.

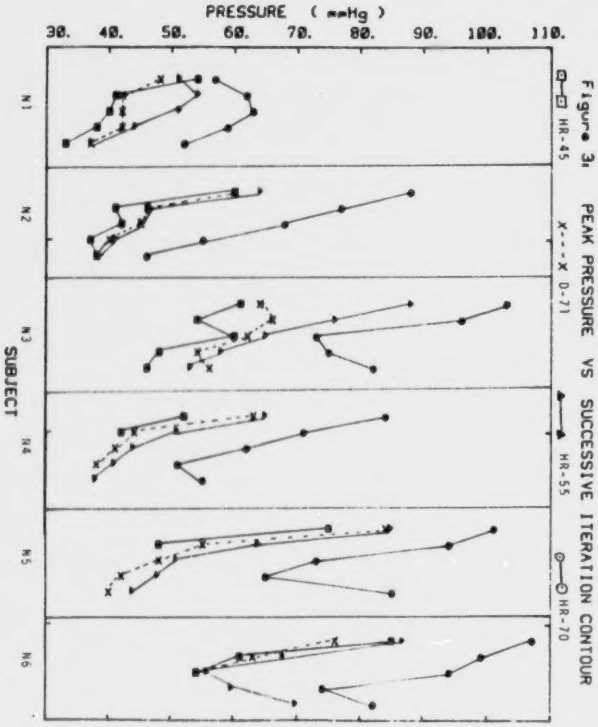

Figure 3: PEAK PRESSURE VS SUCCESSIVE ITERATION CONTOUR

DISCUSSION

The results suggest that the HR-45,D-71 & HR-55 foams provide similar capability to distribute pressure(Peak Pressures 50mmHg) throughout the contoured surfaces using custom contouring for normal subjects. The HR-70 is too stiff and the contours are too shallow in depth for subjects to recognize correct alignment in the contour. Most of the peak pressures occur in the pubis and the midline of gluteal area instead of the I.T. This indicates the need for improving the resolution of the contour gauge to measure body contour precisely. Several variables need further study including W/C seating users, cushion material, lifespan of contoured foam.

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ACKNOWLEDGEMENT

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"SPECIAL INTEREST GROUP". 10

Electrical Stimulation
Stimulation électrique

ICAART 88 - MONTREAL

INTRAFASCICULAR PERIPHERAL NERVE STIMULATION

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The overall aim of this project is to ascertain whether a new type of electrode, implanted into fascicles of peripheral motor nerves, is effective for acute and chronic stimulation of motor neurons to produce stable and graded muscle contraction forces. While we do not expect to develop a clinically useful device directly as a part of this effort, we do hope to develop specifications for what characteristics such a device must have and the benefits that would be derived from its use.

Nerve repair and spinal cord reconstruction are active areas of research that may in the long term lead to direct methods of re-establishing interrupted afferent and efferent pathways in the spinal cord, but until that point is reached, prosthetic devices will have to fill the gap. In the near term neural prostheses of various types show promise as a method of restoring lost function [1]. Various devices that electrically stimulate neural tissue to restore motor control have reached clinical trial stages. These include sacral root stimulators for bladder control, peroneal nerve stimulators for control of foot drop, and phrenic nerve stimulators for diaphram pacing.

Before present techniques of neuromuscular stimulation can serve as clinically acceptable therapies, three improvements are needed: (1) reliable implantable electronics and electrodes; (2) more command channels of volitional control; and (3) somatosensory feedback.

As part of that effort, we have developed recording electrodes which can be chronically implanted within single fascicles of peripheral nerves. We show here that these electrodes are also suitable for electrical stimulation of motor nerve fibers. Therefore, the same electrodes could be used for both stimulation and sensory feedback.

METHODS

Intrafascicular electrodes are threaded longitudinally inside the fascicles of motor nerves and are designed to stimulate nerve fibers that lie in the immediate vicinity of the electrode.

The bipolar electrodes are made from Teflon insulated, 25μm diameter, 90% platinum - 10% iridium wires. Approximately 1mm of the insulation is removed about 20mm back from the end of the wires. The end of one wire is then attached to a sharpened tungsten needle with cyanoacrylate adhesive. The two wires are then threaded through a silastic tube, which is used to lead the wires from the nerve implantation site to an exit zone on the skin.

A salient feature of this electrode design is the relatively large (1mm) stimulation zone. This area (approximately $.08mm^2$) means that small leakage paths due, for example, to breaks in the insulation will not cause significant shunting of current and should not affect electrode performance.

After implantation, the impedance of the electrodes (typically 10 to 20kΩ) is measured with a 1000Hz sinusoidal current injection system. This provides a monitor of the condition of the electrodes and is repeated each time tests are made on the implant.

Rats are anesthetized with 4% choralhydrate given intraperitoneally and maintained with additional doses administered i.p. as needed. The animal is placed on a heated plate to maintain normal body temperature. The sciatic nerve is exposed aseptically in the midthigh region and dissected into its tibial and peroneal branches. The tibial fascicle is isolated. The tungsten needle to which the implanted electrode is attached is used to penetrate the perineurium and pull the electrode through the endoneurium until the exposed stimulating area is centered in the insertion zone. The distal end of the electrode with the attached needle is then cut off. The second electrode is then placed outside the perineurium, forming a bipolar pair. The silastic tube is lead subcutaneously to an exit point over the hips, and the incision is closed with wound clips.

Muscle activation threshold is measured in

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anesthetized animals by applying 200μsec duration pulses through a regulated current isolation unit. Both single pulses and trains of pulses (50Hz for 400msec) are used. Threshold in either case is defined as the minimal current level required to elicit either a visible extension of the unloaded ankle joint or flexion of the toes.

Implants are left in place for three months and tested periodically during this time. After three months, the animal is perfused with phosphate buffered paraformaldehyde and glutaraldehyde fixative, the nerve is exposed and the electrode wires are clipped where they were sutured to the epineurium. The nerve is osmicated and embedded in Epon, leaving the implant in its in-vivo location.

Semi-thin plastic sections above, below and in the center of the implanted region are taken for examination by light microscopy. Areas of particular interest are then thin sectioned for transmission electron microscopy.

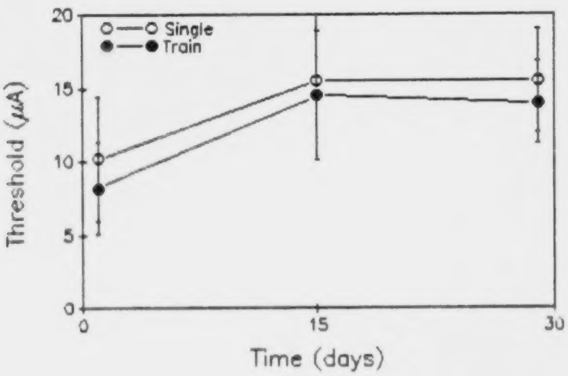
RESULTS and DISCUSSION

Figure 1 shows single pulse and train thresholds as a function of time for six animals implanted with bipolar, intrafascicular electrodes. The average current threshold is on the order of 15μA. This corresponds to a charge density per pulse on the order of 3.75μC/cm². These currents are well over an order of magnitude below levels which have been shown to be safe in stimulating nerves at physiologically meaningful levels with cuff electrodes [3], and the individual pulse charge densities are well below those shown to be safe for both neural tissue and electrode integrity in studies on cortically implanted platimum electrodes [2].

Histological examination of tissue implanted for short periods of time (up to two weeks postimplant) shows little adverse reaction in the tissue, indicating that minimal damage is done to the nerve fibers by the implant procedure or the electrodes.

In addition to the low currents required to elicit muscle contraction, the intrafascicular approach provides a possibility of selecting a stimulation site which minimizes movement and stress on the nerve and electrode leads.

Functional neuromuscular stimulation systems will require multi-channel stimulation, not only because more than one muscle will have to be activated independently, but also because multi-channel stimulation of a single muscle may be needed for avoidance of muscle fatigue in sustained contraction and redundancy in case of failure of electrodes or leads. The localized excitation produced by intrafascicular electrodes, and their relatively small size, makes such multiple-channel implants feasible.



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A CLINICAL PROCEDURE FOR CHARACTERIZING ELECTRODE/MUSCLE OUTPUT

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ABSTRACT

An electrode profiling process has been developed as a tool to determine which electrodes implanted in a particular subject will be used in their FNS hand system, and to determine the parameters that will result in a functionally useful grasp. Each important output characteristic is identified and rated. The characteristics are categorized as: threshold for primary and secondary muscles, primary muscle force, force direction, recruitment gain, length dependency, selectivity and peak impedance. This procedure is a prerequisite to the determination of grasp parameters.

INTRODUCTION

Our laboratory has been implementing neuroprosthetic hand systems for the restoration of palmar prehension and lateral prehension in C5 and C6 tetraplegics over the past ten years. We have developed an electrode profiling procedure in order to chronically monitor the characteristics of the electrode/muscle outputs and as a method for characterizing this output on a clinical basis. Each important output characteristic is identified and rated. The characteristics are categorized as: threshold for primary and secondary muscles, primary muscle force, force direction, recruitment gain, length dependency, selectivity and peak impedance.

METHODS

As a result of much clinical experience we have found a number of electrode/muscle output characteristics that must be determined in order to develop grasp parameters. These characteristics are defined as follows:

Threshold: The threshold is defined as the minimum stimulus necessary to elicit a muscle contraction. It is determined by increasing the pulse duration from 0 uS (amplitude constant at 20mA, stimulus period constant at 80ms) until a visible movement is seen by either the thumb or fingers as a result of muscle contraction. The muscle name and threshold (in microseconds) is recorded. The muscle recruited at the lowest stimulus level is considered the primary muscle. Muscles recruited above this point are referred to as secondary muscles. For muscles which move the fingers it is important to record which digits are recruited since a single electrode rarely recruits all four finger simultaneously.

Primary Muscle Force: The maximum force of the primary muscle just below threshold of any secondary muscles.

Gain: The change in force per change in stimulus or change in position per change in stimulus for the primary muscle.

Selectivity: The percentage of total force recruited by the primary muscle prior to threshold for any secondary muscles.

Direction: The direction of force application or the direction of movement. This parameter is primarily applicable to muscles in the thumb.

Length Dependency: The change in muscle output as a function of wrist and forearm position changes with a constant level of stimulation.

Peak Impedance: The total impedance between the stimulating (cathode) electrode and the reference (anode) electrode.

The electrode profiling process involves observing the output of each electrode/muscle combination and rating them in each category according to a scale of 0, 1, or 2 where 0 = nonfunctional, 1 = adequate, and 2 = excellent. These ratings are made by comparing the electrode/muscle combination output with the output necessary for use in a functional grasp. For example, the primary muscle force for an electrode implanted in the extensor pollicis longus (used for thumb extension in the lateral grasp) could be rated as follows: 0 = does not fully extend the thumb, 1 = fully extends the thumb prior to recruiting other muscles, 2 = fully extends the thumb with additional force resulting in a more stable thumb position. In some cases ratings should also be determined for the secondary muscle if it can be used functionally.

RESULTS

Figure 1 shows an example of the electrode profiling comparison for three electrodes implanted in the thumb extensor for one subject. This particular profile comparison shows that electrode #1 would not be chosen because it has poor selectivity, gain, and length dependence. Electrode #3 would be chosen over electrode #2 because it has superior gain and length dependence properties. If the output of electrode #3 was unacceptable then the implantation of a new electrode or some other compensation would have to be made. This compensation can include surgical alterations, such as tendon transfers, or other measures such as physical therapy to reduce joint stiffness.

DISCUSSION

Electrode profiling provides a means for rating and choosing electrode/muscle combinations to be used in a functional grasp. It provides an initial data base which can be used to determine the parameters necessary to develop a coordinated FNS hand grasp (1). The profiling procedure as presented here requires no special measuring devices or equipment. It is, however, a subjective process. It is totally compatible with a more quantitative approach incorporating various measurement techniques. For example, the primary muscle force parameter could be measured by a pinch meter or force transducer and the rating could be reported in Newtons.

Electrode profiling has already proven to be useful in a clinical setting and is a precursor to the development of a more quantitative approach to characterizing electrode/muscle output using force vector and position output. Electrode profiling will also serve as the basis for early phases of computer automation of the grasp parameter determination process.

ACKNOWLEDGEMENTS

This research is supported by the National Institute on Disability and Rehabilitation Research Grant #G008300118 and the Veterans Administration Rehabilitation Research and Development Service.

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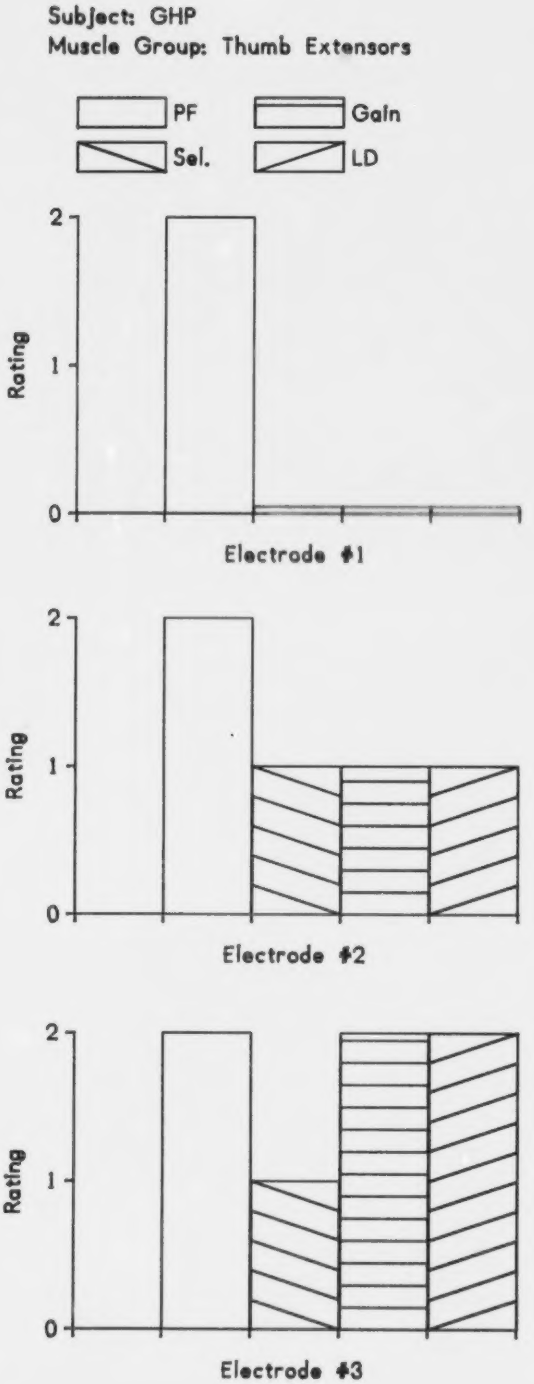

Figure 1. Electrode profiling results for three electrodes implanted in the thumb extensor group. PF = primary muscle force, Sel. = selectivity, LD = length dependency.

STRENGTH AND ENDURANCE CHANGES FOLLOWING ELECTRICAL STIMULATION OF MUSCLES PARALYZED BY SPINAL CORD INJURY

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By using a 4 to 8 week regimen of surface electrical muscle stimulation, we attempted to restrengthen the quadriceps of 24 individuals whose legs were completely (n=12) or incompletely (n=12) paralyzed by spinal cord injury. Those with clinical or electromyographic evidence of lower motor neuron involvement in either leg were excluded. All gave informed consent to an institutionally approved protocol.

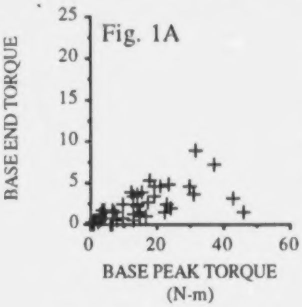
We initially measured the torque produced about the knee, and the decline in this torque during 20 minutes of electrically-induced isometric exercise, in which the legs were held at 60 degrees of knee flexion. Stimulation was applied via water-soaked sponge-covered carbonized rubber electrodes measuring 5 by 10 cm. The indifferent electrode was placed across the quadriceps 3 cm above the superior border of the patella, the active electrode 10 cm above the indifferent. The test stimulus consisted of a 2.5 sec duration, 20 Hz train of 100 mA, 400 µsec compensated monophasic pulses that were delivered in alternating fashion (2.5 sec on, 2.5 sec off) to each leg. We noted the peak stimulated quadriceps torque achieved, the torque remaining after 20 minutes of such exercise (end torque), and the time it took for the torque to decline to 50% of peak (the latter two measures serving to reflect endurance). The subjects next entered a four to eight week reconditioning protocol. Their quadriceps were stimulated twice daily in twenty minute sessions (minimum four hours apart), six days per week. Stimulus currents were set at 120 to 160 mA, with other stimulus parameters as described above. Their legs swung freely during these exercises. The evaluations were repeated at four and eight weeks.

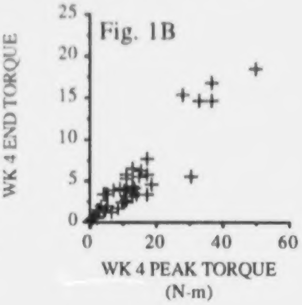
The relationship between peak torque and end torque was variable during the initial baseline measure, with end torque averaging 10 to 15% of the initial peak torque (Figure 1A). In contrast, end torque at 4 weeks was much more closely related to peak torque, with end torque averaging 40% of peak torque, and demonstrating an increase in endurance (Figure 1B). This trend was also apparent after eight weeks; however, only eight subjects participated in the full eight week protocol.

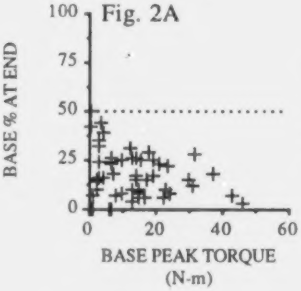
For the initial baseline test, most subjects had end torques that were ≤30% of peak torques (Figure 2A). Only those subjects with peak torques <4 N-m and who were less than 1 year post injury had end torques >30% of peak torque. With the exception of those subjects, most subjects fatigued to 50% of peak torque within the first 5 minutes of stimulation for the baseline evaluations. After four weeks of stimulation, however, more than half of the subjects reached 50% of their initial 4-week peak torque in greater than five minutes, with some subjects still producing greater than 50% of initial peak torque at 20 minutes. Also, all but 1 subject at 4 weeks had end torques that were at least 20% of peak torque (Figure 2B).

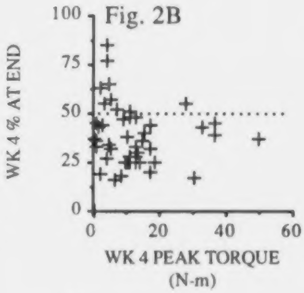
In addition to changes in endurance, increases in initial peak torque over baseline values were also noted at four weeks for about one third of the subjects (Figure 3A). Another third of the subjects showed diminished stimulated strength and the remaining third had no significant change in strength. These inconsistent strength gains contrasted with almost universal endurance gains (Figure 3B). After eight weeks of stimulation however, almost all subjects showed increases in strength. Thus, increases in endurance were more apparent after 4 weeks of reconditioning, while strength increases were more noticeable after 8 weeks.

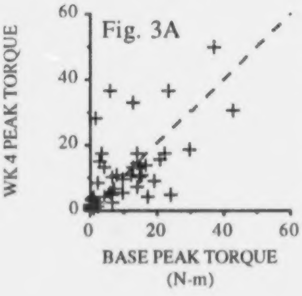
This research was supported by funding from the Veterans Administration Rehabilitation Research and Development Service, from the Vaughan Chapter of the Paralyzed Veterans of America and from the PVA's Spinal Cord Injury Research Foundation.

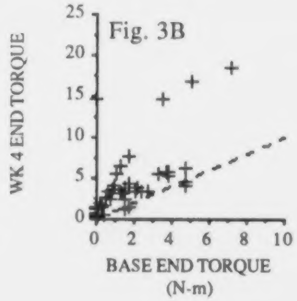












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ISCHIAL BLOOD FLOW IN THE SKIN OF SEATED SCI INDIVIDUALS DURING ELECTRICAL MUSCLE STIMULATION

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ABSTRACT

Ischial skin blood flow was measured in eight seated spinal cord injured (SCI) individuals while electrically stimulating the gluteus maximus muscles. Blood flow was determined by measuring the clearance rate of a radioactive tracer (^{99m}Tc) which was injected intradermally. Recordings were made during both rest and two minutes of electrical muscle stimulation (EMS). Results from four trials met experimental criteria and were used in statistical analysis. Skin blood flow increased during the two minute stimulation in each case, although no statistical significance was found.

INTRODUCTION

Ulceration of the skin often occurs when external forces are applied for a period of time without pressure relief. These sores are referred to as pressure sores, decubitus ulcers, ischemic sores, etc. Pressure sores are a serious and costly problem for many disabled individuals who have lost sensation and are wheelchair dependent. A research study is in progress to determine whether EMS can be used to prevent the formation of pressure sores in SCI subjects. Our previous work in this area has shown that EMS of the gluteus maximus muscle can produce interface pressure variation, tissue undulations, shape reconfiguration of the buttocks under load and an increase in muscle blood flow of the gluteus maximus (1,2).

The etiology of pressure sores involves several parameters, however occlusion of blood flow is a primary factor leading to pressure sore development (3). Occlusion of lymph vessels and disturbance of interstitial fluid flow are also important factors (4,5). The current study was designed to investigate the effects of EMS on skin blood flow over the ischial tuberosities of the seated individuals. Results from this and the previously reported muscle blood flow study (1) are being used to determine effective EMS parameters in clinical trials.

METHODS

Skin blood flow studies were performed on eight SCI subjects. All subjects had a complete sensory and motor paralysis at or above the T_{10} level. None of the subjects had a history of surgery due to pressure sores under the ischial tuberosities.

Subjects were positioned in a seat designed to simulate a standard wheelchair seating position. Seat to back angle was adjusted between 90 and 100 degrees. Leg rests were adjusted so that the surface of the thigh was horizontal and armrests were used. A 2 inch thick medium density vinyl covered polyurethane foam cushion was also used.

Bilateral stimulation was provided via surface electrodes using a portable neuromuscular stimulator[a]. Cathodes were placed over the gluteus maximus muscle at a location which elicited the largest visible contraction for a given stimulation intensity. A common anode was placed at the sacrum. The stimulation frequency was set at 50 Hz. and the intensity as described below. The duty cycle was 2 seconds on, 4 seconds off for 2 minutes.

A pressure monitoring system (6) was used to measure and record changes in seating pressure distribution during EMS (2). This system utilizes an inflatable pressure sensing pad[b] interfaced to specialized computer hardware and software. The pad contains a matrix of switches which open or close independently. A closed switch indicates that the external pressure at the point is greater than the pad inflation pressure. The number of these switches which open or close (number of transitions) during a muscle contraction is related to the strength of the muscle contraction. Stimulation intensity was adjusted to generate 6-8 switch transitions when the pad pressure was set to indicate 10-12 closed switches.

To measure skin blood flow, intradermal injections (.09 ml., 30 μCi) of ^{99m}Tc were first made at each ischial tuberosity. Specific site of injection was determined by requiring the subject to sit in the standard seat for 20 minutes, inducing an area of erythema over each ischial tuberosity. The center of this area was marked with a waterproof marker and an injection was made at that point after the redness cleared.

Tracer washout was recorded using a a wide field-of-view gamma camera that was fitted with a specially designed collimator. The collimator was centered on the injection sites. Sequential scintigraphic images of the injection sites were recorded every five seconds during the experiment. A time vs. activity plot (washout curve) of the ^{99m}Tc washout was obtained for each injection site. The following formula was used to calculate blood flow:

$$\text{Regional blood flow (ml/100g/min)} = 100 \times \lambda \times K$$

where K represents the slope of the washout curve and λ is the partition coefficient (1.0 ml/gm)

The trial consisted of a 30 minute rest period (no EMS) followed by a two minute stimulation period (2 sec on/4 sec off, 50 hz.) and concluding with eight minutes of rest. Subjects were seated throughout and ^{99m}Tc washout was recorded continuously. After this protocol, the subject was placed back on a stretcher and a thorough skin inspection was performed.

RESULTS

The skin inspection which was performed following the test protocol revealed that for several cases, the injection site occurred outside the area of redness induced at the ischial tuberosity as a result of sitting. For these cases the subjects sitting posture during the test period did not duplicate the pretest sitting posture. Of the 8 SCI subjects tested, only 5 injection sites proved to be within the area of erythema. In addition, for one of the subjects, the EMS intensity was set too low to induce any noticeable movement. Therefore statistical analysis was performed on only 4 sets of data. A paired t-test was performed to compare the average blood flow during the rest period before stimulation with blood flow during the two minutes of EMS. Although no statistically significant difference was found, in all cases there was increased blood flow during EMS (see Table 1).

Subject #	Rest* (10 min.)	Stim. (2 min.)	Rest (last 8 min)
1	0.008	0.026	0.012
2	0.007	0.015	0.017
3	0.000**	0.005	0.001
4	0.000**	0.027	0.000**

* average blood flow for the 10 minutes immediately preceding EMS

** in these instances the washout curve was essentially flat indicating no blood flow

Table 1. Summary of skin blood flow results (all units in ml/100g/min)

DISCUSSION

The results from this paper indicate a trend toward increased skin blood flow with EMS. Note also that the blood flow values listed in the last column of Table 1 (Rest - last 8 min after stim) are generally larger than the blood flow just previous to EMS (Rest - 10 min before stim). This indicates that skin blood flow may not only increase during EMS, but it also may tend to stay increased for several minutes following EMS.

Measurements of skin and muscle blood flow are important parts of determining the efficacy of EMS for pressure sore prevention. In addition to the results in this paper on skin blood flow, an increase in muscle blood flow has also been reported (1). Stimulation patterns (frequency, duty cycle, intensity) have remained the same throughout these trials. Further studies will investigate a range of stimulation parameters in an effort to find the most effective ones for increasing skin and muscle blood flow.

Due to the problems encountered in locating the appropriate injection site for the radio active tracer, laser doppler flowmetry is being pursued as an alternative means for measurement of skin blood flow. A flat laser doppler dermal probe (< .25 in thick) has been developed[c] which should minimally impact on the dynamics and shape of the seating interface. In addition, laser doppler flowmetry offers many advantages: 1) Placement of the probe can be done after the subject is sitting so that blood flow measurement over the ischial tuberosities or another areas of high pressure is ensured; 2) It is a non-invasive procedure; 3) Real-time results are available; 4) The required sampling duration is much shorter; 5) Positioning of the subjects should not be a problem because they will be able to sit in their own wheelchair; 6) All of the equipment is portable and can be conveniently used in various settings.

CONCLUSION

Increased skin and muscle blood flow during EMS support the hypothesis that EMS may be useful in preventing pressure sores. However these results do not guarantee success since there are also many negative effects which must be considered (increased oxygen consumption, metabolite production, sweating, etc). Clinical trials are now in progress to further evaluate the efficacy of EMS for preventing pressure sores. Blood flow studies will also be continued in an attempt to optimize EMS parameters for pressure sore prevention.

ACKNOWLEDGEMENT

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SUPPLIERS

a. Respond II Stimulator, Medtronics, Inc.,
7000 Central Ave. NE, Minneapolis, MN 55432
b. TIPE pressure pad, TK Applied Technologies,
11915 Meadowtrail Lane, Stafford, TX 77477
c. Medpacific Corporation,
6701 sixth Ave South, Seattle, WA 98108

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CARDIOVASCULAR RESPONSES TO FNS-INDUCED ISOMETRIC LEG EXERCISE DURING ORTHOSTATIC STRESS IN PARAPLEGICS

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INTRODUCTION

Confinement to a wheelchair following spinal cord injury (SCI) is usually associated with degenerative sequelae including muscle atrophy, loss of bone integrity, fatigue during daily activities, and a generalized decrease of health, physical fitness and active lifestyle often progressing to cardiovascular disease. A serious problem limiting the exercise capacity and physical performance of SCI individials is inadequate venous return of blood to the heart and a reduced cardiac output during exercise ("circulatory hypokinesis") consequent upon peripheral venous pooling in the lower extremities (1). Davis and colleagues (2) have demonstrated that functional neuromuscular stimulation (FNS) is effective for inducing rhythmic static contractions of paralyzed leg muscles, thereby "reactivating" the skeletal muscle venous pump and augmenting cardiac output ($\dot{Q}$) and stroke volume (SV) during arm crank exercise. Glaser and co-workers (3) have also observed that peripheral FNS increased $\dot{Q}$ and SV at rest in able-bodied and paraplegic subjects in both the supine and upright seated postures. However, these previous studies have employed FNS-induced muscle contractions to attenuate venous pooling and augment central circulatory performance in postures of low orthostatic load (ie. supine or sitting upright). Therefore, the purpose of the present investigation was to determine if FNS-activated isometric contractions of paralyzed lower-limb musculature were effective for reversing venous pooling induced by progressive orthostatic challenge in paraplegic men.

METHODS

Eight asymptomatic SCI men (age=34.0 ± 4.1 yr), significantly disabled by neuromuscular deficits but otherwise healthy, were recruited for the present study. Their functional levels of SCI ranged from T_4 to T_{10}. Following 1-3 weeks of FNS habituation, the subjects underwent an orthostatic challenge test consisting of 15-min progressive upright tilting at -10°, 0°, 30° and 70°. At each tilt angle, subjects experienced 5-min of rest (REST), 5-min of FNS-induced muscle contractions (STATIC) and 5-min of recovery (REC). FNS-induced leg exercise encompassed rhythmic, asynchronous, isometric contractions of hamstrings, quadriceps, gastrocnemius and tibialis anterior. An 8-channel electrical stimulator (4 muscle groups on each leg) provided the asynchronous pattern of thigh-calf static contractions. Stimulation characteristics consisted of biphasic pulses of 0.3 msec width at 35 Hz, delivered through surface electrodes over the neuromuscular motor points (2, 4). A duty cycle of 1.5 s (ie. 1.5 s on and 1.5 s off) was employed to ensure a significant neuromuscular activation. The intensity of stimulation was adjusted to induce vigorous pulsatile contractions in each muscle group. Four men exhibiting vigorous contractions were classed a 'responders' (R) to FNS, while the remaining subjects served as 'non-responder controls' (C).

Central hemodynamic responses ($\dot{Q}$, SV, and indices of myocardial performance) to orthostatic challenge were assessed using impedance cardiography. Heart rate (HR), oxygen uptake ($\dot{V}O_2$) and expired ventilation ($\dot{V}_E$) were determined from ECG during open circuit spirometry. Arteriovenous oxygen extraction ($a\text{-}\bar{v}O_2$ diff) was calculated from $\dot{V}O_2$ and $\dot{Q}$. Total peripheral resistance (TPR) was estimated from $\dot{Q}$ and ausculated blood pressures (DBP, SBP). The physiological data were analyzed using a three-way analysis of covariance to assess differences between groups (R versus C), among conditions (REST, STATIC and REC) or across tilt angles (-10°, 0°, 30° and 70°). Differences of physical characteristics and hemodynamic responses during orthostatic challenge were considered significant at the 5% level.

RESULTS

Cardiac outputs during FNS-induced isometric leg exercise (STATIC) were significantly augmented for R subjects (by 0.90-2.17 $l \cdot min^{-1}$ at -10° to 30° tilt; Figure 1) compared to non-FNS conditions (REST & REC). The increases of $\dot{Q}$ were coincident with enhanced SV (11-23 $ml \cdot beat^{-1}$; Figure 2) in the absence of any differences in exercise HR or TPR. Steady-state $\dot{V}O_2$ was increased above rest for R at low tilt angles (by 25-58%; $p \leq .05$) despite an unchanged $a\text{-}\bar{v}O_2$ diff. Although DBP was not different among FNS and non-FNS conditions, SBP was elevated during STATIC by 7-16 mmHg ($p \leq .05$). There were no hemodynamic or metabolic alterations for C subjects during tilt and FNS-induced muscular contractions.

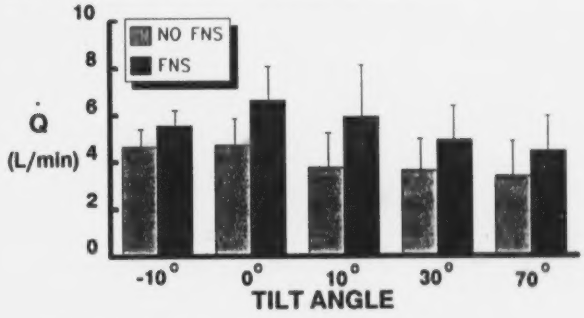

Figure 1. Cardiac output ($\dot{Q}$) during upright tilting in 'Responders' to FNS. Values are means ± SE.

DISCUSSION

An important issue raised by several authors (1, 3, 5) has been the extent to which circulatory hypokinesis arising from lower-limb venous pooling or other consequences of autonomic impairement affects exercise capacity and physical performance of SCI individuals. The inability to activate the peripheral "muscle pump" via voluntary contractions of leg muscles may limit venous return of blood to the heart, restrict cardiac output and impede adequate blood flow to the active upper-body muscles. Consequent upon insufficient availability of oxygen and fuel substrates would be an early onset of fatigue in the disabled population. The major findings of this study were a marked enhancement of cardiac output and oxygen uptake during FNS-induced leg contractions (STATIC) under conditions of low orthostatic stress.

At tilt angles ranging from -10° to 30°, $\dot{Q}$ was significantly increased by 25-58% (0.90-2.17 $l \cdot min^{-1}$; Figure 1) corresponding to a similar proportionate increment of steady-state $\dot{V}O_2$. These data are consistent with recent observations by Davis and colleagues (2) who reported a 39% increase of resting $\dot{Q}$ and 7-8% elevation of exercise $\dot{Q}$ in the upright seated posture during FNS-stimulation. Both our earlier work and the present study support the view that cardiovascular performance may be significantly enhanced by FNS-induced pulsatile isometric contractions which "reactivate" the skeletal muscle pump to produce an enhanced venous return from peripheral compartments. On the other hand, the lack a significant FNS effect upon cardiac output at high tilt angles (70°) may reflect the inability of this technique to empty the venous pool in paraplegics under conditions of high orthostatic challenge (nearly 95% of gravitational loading).

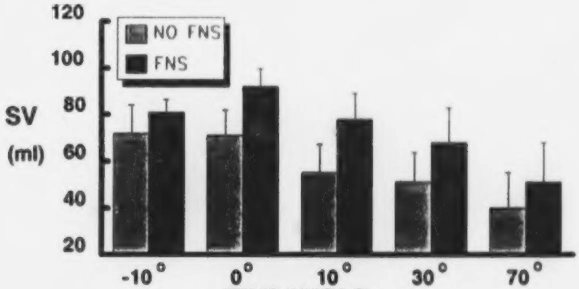

Figure 2. Stroke volume (SV) during upright tilting in 'Responders' to FNS. Values are means ± SE.

Augmented $\dot{Q}$ at low tilt angles could be solely attributed to increased SV (by 13%-42%; Figure 2) as both HR and TPR were unchanged during FNS-induced contractions. From a physiologic viewpoint, it appears that increased volume loading of the heart (greater ventricular filling and preload) may provide a more advantageous overlap of myofilaments increasing the force and velocity of cardiac contractions (Starling Effect) without altering myocardial O_2 demand. Conversely, an unchanged TPR suggested that FNS does not alter cardiac afterload.

CONCLUSIONS

Augmented central hemodynamic responses during FNS-induced isometric leg exercise support the view that circulatory hypokinesis in paraplegics may be partially reversed during low-intensity orthostatic challenge (upright tilting) by FNS-induced reactivation of the skeletal muscle pump. Further research is required to determine if the site and degree of spinal cord lesion or the quantity and quality of effective muscle mass "reactivated" by FNS play a role in modifying upper-body exercise capacity.

ACKNOWLEDGEMENTS

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FNS-ASSISTED VENOUS RETURN IN EXERCISING SCI MEN

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INTRODUCTION

In the spinal cord injured (SCI) population, impaired sympathetic cardiac and vasomotor control, physical deconditioning, and/or compromised respiratory and venous muscle pumps may allow excessive venous pooling in the lower extremities. Consequently, inadequate venous return and cardiac output ($\dot{Q}$) responses to exercise ("circulatory hypokinesis") may limit the arm exercise capacity of SCI individuals by limiting blood flow to the skeletal muscles. Glaser and colleagues (1) have found that functional neuromuscular stimulation (FNS) of paralyzed leg muscles improved central hemodynmaic performance of both able-bodied and paraplegic subjects at rest in the upright sitting posture by significantly increasing $\dot{Q}$ and stroke volume (SV) . Davis and coworkers (2) used this FNS application with paraplegics in the sitting posture and reported FNS-induced increases of $\dot{Q}$ and SV during arm-crank exercise (ACE). FNS appears to reactivate the skeletal muscle venous pump, reverse peripheral venous pooling, and enhance venous return. Further investigation with this FNS technique is necessary with additional control of subject posture during ACE. Therefore, the purpose of this study was to determine the effects of FNS upon venous return in SCI men performing ACE in different postures. It was hypothesized that FNS-enhancement of venous return may vary with the magnitude of the orthostatic load and venous pool.

METHODS

Six healthy male SCI subjects volunteered to participate in this study. Their mean (± SE) age, height, and mass were 34 ± 5 yr, 183 ± 3 cm, and 84 ± 5 kg, respectively. Functional levels of SCI ranged from C7 to T12. Subjects performed light-intensity (12.5 W), steady-state ACE at 0^{o}, 30^{o}, and 70^{o} while lying on a tilt table. At each angle, subjects underwent 5 min of rest, 5 min of ACE alone, 5 min of rest (recovery), 5 min of ACE with FNS applied to paralyzed leg musculature, and 5 additional minutes of rest. FNS consisted of biphasic electrical pulses of 0.3 msec pulse width at 35 Hz delivered through surface electrodes over motor points. FNS was applied with an eight-channel stimulator to thigh (quadriceps and hamstrings) and calf (gastroc-soleus and tibialis anterior) muscle groups bilaterally in an alternating pattern with a 1.5-sec ON-OFF cycle. The intensity was adjusted to induce vigorous pulsatile static contractions. Central hemodynamic responses ($\dot{Q}$ and SV) to ACE and ACE+FNS were assessed with impedance cardiography; heart rate (HR) was determined from ECG. Oxygen uptake ($\dot{V}O_2$) was monitored with open-circuit spirometry. Arterial systolic blood pressure (SBP) was estimated by auscultation. Arteriovenous O_2 difference ($a\text{-}\bar{v}O_2$) and rate-pressure-product (RPP) were calculated. The physiological data were analyzed with two-way repeated-measures analyses of variance and with two-tailed dependent *t*-tests between ACE and ACE+FNS conditions at each tilt angle.

RESULTS

During ACE at 0^{o} and 70^{o} tilt angles, FNS application did not significantly increase the levels of $\dot{V}O_2$, $a\text{-}\bar{v}O_2$, $\dot{Q}$, SV, HR, SBP, or RPP. In contrast, during ACE at 30^{o}, FNS produced an 18% (1.37 L/min; $p<.001$) increase of $\dot{Q}$, a 16% (11 ml; $p<.02$) increase of SV, and a 14% (1.89 ml/100ml; $p<.05$) decrease of $a\text{-}\bar{v}O_2$. There were no significant changes of $\dot{V}O_2$, HR, SBP, or RPP during FNS application. Figures 1 and 2 illustrate the effect of FNS on $\dot{Q}$ and SV (ie. venous return) during ACE at each tilt angle.

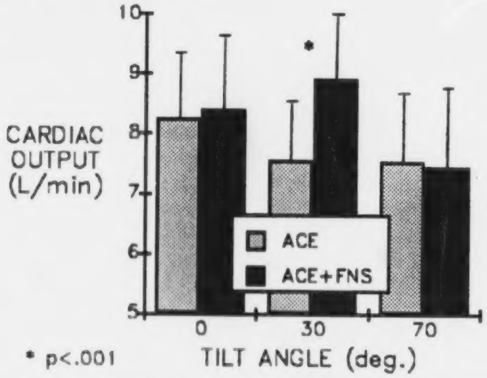

Figure 1. **Mean (± SE) cardiac output of seven paraplegic men during ACE and ACE+FNS.**

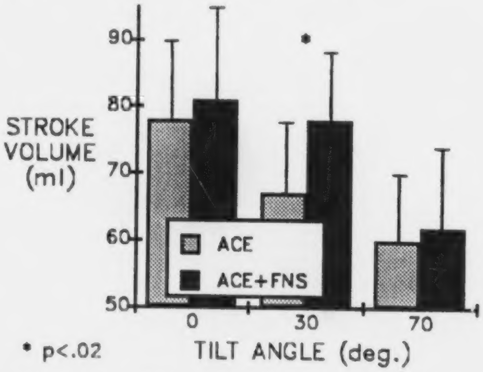

Figure 2. Mean (± SE) stroke volume of seven paraplegic men during ACE and ACE+FNS.

DISCUSSION

The differences of $\dot{V}O_2$ between ACE and ACE+FNS at each tilt angle were small and nonsignificant (1-7%). This finding confirms our previous research that had suggested minimal aerobic metabolic consequences of pulsatile static FNS of eight lower-extremity muscle groups (1-4).

The major findings of this study were the statistically significant 18% and 14% increases of $\dot{Q}$ and SV, respectively, produced by FNS during ACE at the 30° tilt angle. These effects are consistent with recent observations by Davis and coworkers (2) who reported 7-8% and 10-26% FNS-induced increases of $\dot{Q}$ and SV, respectively, during ACE in upright paraplegics. Therefore, FNS-induced pulsatile static contractions can activate the venous muscle pump and enhance return of venous blood from peripheral body segments to the heart.

This FNS-enhancement of venous return, however, may be dependent upon the magnitude of the orthostatic load and resulting venous pool (as represented by the tilt angle). The 0° tilt angle (supine) would not be expected to induce venous pooling, and hence, the minimal effect of the FNS-activated muscle pump on venous return during ACE. In contrast, the 30° tilt angle involved moderate (50%) orthostatic loading with probable venous pooling; the effect of FNS here was to enhance cardiac preload and to elevate $\dot{Q}$ and SV to the high levels seen in the supine posture. However, at the 70° tilt angle, the lack of elevated $\dot{Q}$ and SV may indicate an inability of the present FNS technique to effectively move the venous pool against the nearly full (94%) orthostatic gravitational load. The lack of enhanced venous return during ACE at 70° suggests that the presently used FNS venous pump may be limited by the gravitational load or weight of the venous pool.

The FNS-induced decrease of calculated a-$\bar{v}O_2$ during ACE at 30° can be attributed to the increase of $\dot{Q}$ while $\dot{V}O_2$ remained constant (a-$\bar{v}O_2 = \dot{V}O_2 / \dot{Q}$). This indicates that the FNS-enhanced venous return during ACE increases systemic O_2 transport while reducing the rate at which tissues need to extract O_2.

The FNS-induced increase of $\dot{Q}$ during 30° ACE can be attributed solely to FNS's effect on SV, since FNS had no influence on HR ($\dot{Q}$ = HR x SV). This provides evidence that the FNS-induced venous muscle pump enhances ventricular filling and preload, and subsequently allows the Starling effect to increase myocardial performance. In addition, since FNS during 30° ACE did not increase HR, SBP or RPP, this increased cardiac volume-loading seemed to impose no additional myocardial O_2 demand or stress.

CONCLUSIONS

In conclusion, FNS-induced pulsatile static contractions of paralyzed leg musculature activates the venous muscle pump in spinal cord injured subjects during voluntary arm crank exercise. FNS appears to enhance venous return during arm-crank exercise most effectively during moderate orthostatic loading with probable venous pooling. Therefore, this FNS application may attenuate circulatory hypokinesis during exercise in this population.

Future research needs to determine if this FNS technique can improve voluntary upper-body exercise capacity in spinal cord injured individuals. To test this hypothesis, investigators need to quantify (a) the reduction of lower-body venous pooling, (b) the redistribution of the enhanced venous return and cardiac output to the arms during maximal or prolonged submaximal exercise, and (c) the increases of maximal power output and endurance for arm exercise when FNS is applied to the lower limbs.

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CANDIDATE SELECTION FOR USE WITH A FUNCTIONAL NEUROMUSCULAR STIMULATION HAND SYSTEM

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ABSTRACT

Our laboratory has demonstrated that the application of a functional neuromuscular stimulation hand system for C5 and C6 tetraplegics provides functional restoration of hand grasp utilizing both a lateral and palmar prehension and release. The selection criteria for candidacy in our program includes physiological criteria, psychological criteria, and adequate support mechanisms. There are several stages of patient participation depending upon factors which include how independent they are with their hand system, the potential augmentation of the hand performance with surgical intervention, and the availability of the refinement of new technology such as implantable stimulators. The selection criteria is an evolutionary process which is modified to include additional requirements at each level of participation.

INTRODUCTION

A FNS neuroprosthetic hand system has been developed and is in use with C5 and C6 tetraplegics. Our experience has shown the need to progress towards an implantable neuroprosthetic systems to increase reliability and to minimize attendant support necessary in the maintenance of the present percutaneous electrodes. A patient initially begins with a percutaneous device. The next stage is an evaluation for surgery to augment the percutaneous device and the last stage is the implementation of an implantable system. If both the hand surgery and implant system can occur at the same time without compromise to either, the procedures are performed simultaneously. However, our experience has shown that for proper post-operative management and length of surgery, it may be necessary for these procedures to be performed at separate stages. At each stage the patient is required to pass additional criteria. Patients are not required or encouraged to continue to the next stage if they are unable to meet the necessary criteria. We have had 27 patients in our program of which 5 have had augmentative surgery and 1 patient has had an implantable stimulation system. The following outline lists the criteria necessary at each stage.

STAGE I IMPLEMENTATION OF A PERCUTANEOUS NEUROPROSTHETIC HAND SYSTEM

Physiological Criteria

1. Stable neurological status
2. Absence of complicating medical problems, i.e. infections, diabetes, heart disease, skin breakdowns, uncontrolled spasticity.
3. Intact vision
4. Optimal physiological rehabilitation
    a. good sitting tolerance
    b. good sitting balance, or mechanisms to substitute for lack of trunk control
    c. good strength in voluntary muscles
    d. independent wheelchair mobility
    e. minimal upper extremity contractures
    f. patient has been rehabilitated to optimal level of independence using traditional orthotic devices, etc.
5. Minimal hypermobility or joint laxity in instrumented hand
6. Preferably some residual sensation in the hand, but not necessary. No intolerable hypersensitivity in the instrumented arm.
7. Adequate shoulder and elbow control to enable patient to position hand for function.
8. Adequate wrist strength to stabilize hand (grade 4), or static wrist support.
9. Key muscles for stimulation must have lower motor neuron intact, optimally all of the following muscles are intact. We may be able to provide a grasp without all these muscles depending on what muscles are available, and the characteristics of each muscle/electrode response.
    Flexor pollicis longus or brevis
    Abductor pollicis longus or brevis
    Adductor pollicis
    Extensor pollicis longus or brevis
    Extensor digitorum communis
    Flexor digitorum profundus
    Flexor digitorum superficialis
10. Consideration for tendon transfer of voluntary muscles to improve hand grasp must be ruled out for all C6 candidates with grade 4 or better wrist extensors.

Psychological Criteria

1. Adequate ability to cope with his disability
2. Possesses an optimistic and motivated attitude with realistic functional goals

3. Normal cognitive function, to operate the system and understand how it functions.
4. Patients are encouraged to become very active in the research, to provide us with input and suggestions to improve the device.

Support Criteria
1. Patients are dependent on family or attendants to maintain the skin interface, don the system in the A.M., to set up exerciser in the evening, and possibly for transportation to and from the hospital. The patients success is dependent on regular use and compliance.

STAGE II AUGMENTATION OF SYSTEM BY SURGICAL INTERVENTION

Patients in this category are at least 1 year post injury, have successfully completed the above criteria and have demonstrated functional abilities to use the percutaneous system for at least six months.

Physiological Criteria
1. A comprehensive medical history and physical evaluation is performed to determine that the patient is not under increased risk due to surgery.
2. A comprehensive evaluation of hand performance using the percutaneous neuroprosthesis is performed by the clinical team, which is composed of a rehabilitation engineer, orthopedic surgeon, and therapist, to determine if the patient would benefit from surgical techniques commonly used with other hand injuries to augment his system. For example, an intrinsic plasty to prevent clawing and to provide active MP flexion has shown to be beneficial since we do not currently activate the interosseus or lumbrical muscles.
3. A comprehensive evaluation of hand performance without the neuroprosthesis is performed by the clinical team to determine whether the patients hand performance without the neuroprosthesis would also benefit or remain unchanged from the intended surgery.
4. If the postoperative program coincides with the postoperative plans for an implanted device the patient must also complete the criteria for an implantable stimulator.

Psychological Criteria
1. The patient is informed and understands the purpose of surgery, the risks, and the post operative procedures.
2. The patient continues to be motivated, and has realistic goals.

Support Criteria
1. Adequate health insurance
2. The patient will be asked to follow a strict post operative protocol and will require family, or attendant support to assist with therapy, follow up visits, and increased dependance while in protective dressing.

STAGE III IMPLEMENTATION OF AN IMPLANTABLE STIMULATOR

The above criteria are successfully completed. The patient has undergone any hand surgery that would not be appropriate at the time of implantation.

Physiological Criteria
1. A comprehensive medical history will be taken to confirm that the patient has no prior history of a major chronic systemic infection or other illness which would increase the risk of surgery.

Psychological Criteria
1. Patients will be provided psychological counseling and a standardized test (MMPI) will be performed to insure proper patient selection and support.

Support Criteria
1. Presently patients must be from the Northeastern Ohio area, to allow for close monitoring of the device.
2. Patients will be required to return for follow up visits and studies regularly for over one year, and family or attendant support will be required as above for postoperative care.

SUMMARY

Patients using a functional neuromuscular prosthesis are targeted to complete each of the stages described and to receive an implanted device. If the patient does not meet the necessary criteria to move to the next stage then he continues to function at the existing stage he has achieved. We believe that patients must meet the above physiological, psychological and support criteria consistent with each of the stages in our program to be successful user.

ACKNOWLEDGEMENTS

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CLOSED-LOOP REGULATION OF GRASP STIFFNESS FOR FNS RESTORATION OF HAND FUNCTION

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ABSTRACT

A combined open and closed loop system for controlling hand grasp during functional neuromuscular stimulation has been implemented in a clinical laboratory. The closed loop system (using feedback from contact force and position sensors) regulates grasp opening and force during manipulation tasks, providing linear and repeatable control characteristics for the user.

INTRODUCTION

Functional Neuromuscular Stimulation (FNS) has been used successfully for the restoration of hand grasp/release in subjects with spinal cord injury at the C5 and C6 levels [eg. 4,5]. In these systems, patients must make all corrections for nonlinearities or temporal variations in the output of the electrically stimulated muscles by voluntarily adjusting the command signal. In this report, we describe the clinical implementation and testing of a closed loop hand grasp control system that automatically compensates for muscle nonlinearities and time dependencies.

When the hand is used to grasp and manipulate objects, it encounters loads of greatly varying characteristics. Prior to contact, the hand is unloaded and the muscles work only against internal and gravitational loads, while when grasping a rigid object, the loading conditions can be nearly isometric. Because of the different loading conditions, a single parameter feedback control system (eg force or position) can not provide regulation during all phases of grasp. A feedback control system employing a weighted sum of grasp opening and contact force signals provides regulation of the stiffness of the grasp. Stiffness regulation can compensate for nonlinearities and time variations under the full range of loading conditions, giving linear and repeatable control of grasp. The stiffness regulator also allows the control of grasp with a single input command signal, and does not have to switch among different operating modes for different types of loads.

METHODS

A diagram of the FNS grasp control system is shown in Fig. 1. Two different control systems, one open loop and one closed loop, are used to control the digits forming the grasp. In lateral prehension and in palmar prehension, the fingers and the thumb provide opposite functions and are controlled in opposite modes. In lateral prehension, the fingers are activated under open loop control to flex and form a platform to support the forces generated by the thumb as it presses against the side of the index finger: the movements of the thumb are under closed loop control. The opposite occurs during palmar prehension: in this case the thumb is brought into opposition under open loop control and the fingers are under closed loop control.

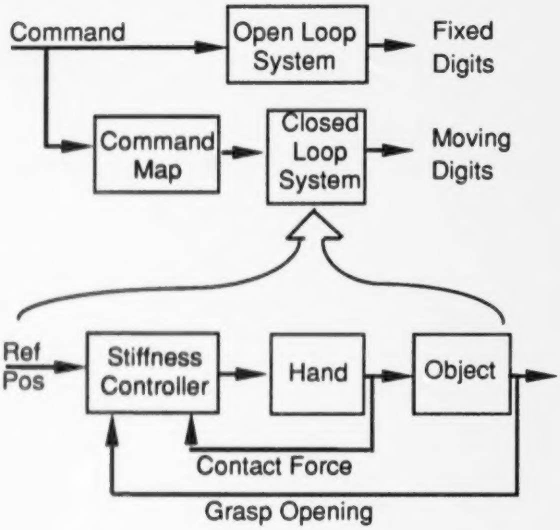

Figure 1. Block diagram of hand grasp system.

The input command is a continuously gradable signal that is used to control the overall grasp, with one extreme indicating a fully open hand and the other extreme indicating a maximal strength grasp. It is generally derived from the patient's voluntary movement of the contralateral shoulder. The command signal is used a) to directly modulate the stimulus parameters applied to the muscles controlling the digit that is under open loop control and b) to generate a reference value of grasp opening (via the comand map) for the stiffness regulation system.

The stiffness regulator [1,3] combines feedback from grasp force and grasp opening sensors to automatically adjust the stimulus parameters to maintain a fixed ralationship between the reference position, the actual grasp opening and the grasp force, according to the equation

$$\text{force} = \text{stiffness} * (\text{reference} - \text{grasp opening}).$$

Prior to contact with an object, the grasp opening is equal to the reference signal coming from the command map (no force exerted); after contact, the force on the object is proportional to the difference between the reference and the actual opening.

The system is being tested in the laboratory with spinal cord injury subjects that have previously received a portable hand grasp system. The control systems are implemented in a PDP-11/73 laboratory computer. Command signals are generated by the computer or by the patient through their neuroprosthesis. Grasp opening is measured with a position sensor [2] mounted on the dorsum of the hand measuring movement of either the index finger or the thumb. Grasp force is derived either from a wearable force sensor on the thumb [6], or from special objects that have been instrumented with strain gages.

The parameters of the system are set according to an established protocol. Recruitment characteristics of the muscles are used to set the parameters of the open loop system, the command map and the majority of the parameters in the stiffness controller. The gain of the closed loop controller is adjusted to tune dynamic response of the system for step inputs. The regulated stiffness is set equal to the ratio of maximal grasp force to maximal grasp opening, to divide the available command range equally between position control and force control (when grasping a very thin object).

RESULTS AND DISCUSSION

The system has been studied under laboratory conditions with two subjects to date. Performance has been tested during unloaded position control, isometric force control, and simultaneous control of force and position with compliant loads. Control during transitions between unloaded and isometrically loaded conditions have also been studied.

An example of the results is shown in Fig. 2. In this test, the subject controlled the command to grasp, pick up and release an instrumented object using lateral pinch. The command (cmd), grasp opening (pos), and normalized grasp force (for) are plotted as functions of time. Increasing position (up) represents thumb extension; increasing force (down) represents increasing contact force in flexion. Force is normalized to the regulated stiffness (K).

As the command ramped from extension to flexion (top to bottom), the grasp opening decreased and the contact force increased. Simultaneous changes in force and position were due to the compliance of the hand. Force was well regulated during the maintained flexion and lifting of the object and no problems were encountered in the transition betweeen position control and force control.

ACKNOWLEDGEMENTS

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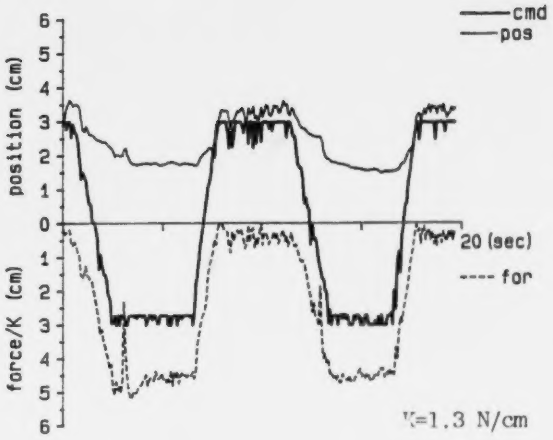

Figure 2. Force and postion control during grasp and release

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ADDRESS FOR CORRESPONDENCE

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Functional Evaluation of an FNS Hand Orthosis: A Case Report

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INTRODUCTION

The increasing number of technical resources available for the disabled, from robotics and environmental control systems to neural prostheses, demands that clinicians and patient consumers develop systematic methods of decision making regarding the choice of technical aid. Decision making is fostered through the evaluation of priorities and needs of individuals and through the systematic study of the advantages and disadvantages of the variety of technologies available. Clinical research designed to assess the functional impact of applied technology provides the basis for determination of the value of products to individual consumers.

One example of a new technology is the Functional Neuromuscular Stimulation (FNS) hand orthosis (Case Western Reserve University/ VA Medical Center, Cleveland, Ohio) which offers controlled prehension and release to individuals with C5 quadriplegia who are otherwise dependent on bimanual prehension or a weak tenodesis grasp. A collaborative pilot study focusing on the transfer of this technology to a satellite centre at the University of Toronto is in progress. In addition to accomplishing the technology transfer, a goal of the research in Toronto is to provide a functional evaluation of the FNS orthosis. It has been reported that the orthotic system enhances function in isolated tonic prehension tasks such as holding a fork (1). Further demonstration of performance of individuals using the orthosis in a variety of activities of daily living tasks would allow useful comparison of the orthosis with other available treatment methods.

Individuals with C5 quadriplegia prehend objects employing a passive bilateral grasp achieved by adducting the hands to midline. Good power in shoulder abduction, flexion, and elbow flexion in addition to variable strength (grade 0-3+) in wrist extensors contribute to this functional pattern. However, lack of elbow extension together with scapular and trunk instability limit reach and therefore use of prehension at a distance in vertical and horizontal planes. The presence of such limitations in proximal control raises questions about the potential for functional use of a technically superior prehension system for the performance of activities of daily living.

CLINICAL EVALUATION

To ensure comprehensive and objective evaluation of the application of this technology, a tool was required that allowed comparison of an individual's performance with the FNS orthosis versus their usual prehension pattern (unilateral or bilateral function). Thus important components of a functional evaluation include:

a) Performance of functionally relevant tasks scored to allow performance using bilateral or unilateral prehension and allowing free choice in the selection of performance method;

b) Prehension of objects of varying sizes, shapes and weights in a variety of horizontal and vertical planes;

c) Performance of prehension tasks over time to permit evaluation of endurance; and

d) Measurement of accuracy and speed to allow a meaningful comparison to performance with and without the FNS orthosis.

Review of the literature failed to identify a validated hand function test that could meet all of the above criteria (Box and Block Test, Jebsen, Upper Extremity Function Test, Sollerman, Nine Hole Peg Test, Minnesota Dexterity Test (2,3,4,5,6,7). Therefore, design of a tool to evaluate the functional value of the FNS orthosis was undertaken. In its present form the evaluation consists of four subtests designed to look at static and dynamic aspects of grasp including speed and accuracy of performance. All subtests are administered to the subject with and without the FNS orthosis.

1. The pick-up task: designed to measure the ability to grasp and release objects of a variety of sizes, shapes and weights. This subtest requires subjects to pick-up objects placed two inches lateral to midline and transfer them across a one inch barrier to be released, thus crossing the midline. The task is repeated with two blocks of the same mass (1.5 inches and 3.5 inches), with weighted cylinders of the same diameter, (30 grams and 750 grams), and with two envelopes (one empty and one weighted).

2. The pick-up and place test: designed to assess prehension when incorporated with reach in horizontal and vertical planes. This test requires the subject to prehend,transfer and release five objects including a computer disc, a paper cup filled with water,a book, a tennis ball and a quarter in a variety of planes.

Subtests one and two are timed from the start command to task completion or to a maximum limit of 60 seconds. This provides measurements of successes and failures as well as a measure of efficiency. A descriptive key enables observers to detail the prehension pattern employed providing qualitative information to assist in data interpretation.

3. The modified Box and Block Test: designed to assess gross dexterity and endurance. This subtest requires the subject to prehend one inch blocks preplaced to the side of a one inch barrier and to lift them over the barrier. The number of blocks moved in 30 seconds is recorded. There is a 30 second rest period and the test is repeated for a total of 10 trials.

4. The Integrated Tasks Test: designed to assess the ability to perform a sequence of prehension tasks(requiring different grasp patterns). This test simulates the set up of a work area with a telephone,pen and paper, glass,jug filled with water and plate and fork. The subject is asked to perform a series of functionally relevant tasks requiring that he alter grasp patterns inbetween activities (8).

RESULTS

Preliminary testing of the functional evaluation was accomplished by administering the test to six subjects: three with C5 quadriplegia and wrist extensor strength of grade 3 and three with C6 quadriplegia and wrist extensor strength of grade 4 or greater. The six subjects were rated for hand function ability by occupational therapists and the rating was compared with the relative test performance using two of the subtests. Combined scores for the pick-up and pick-up and place tasks ordered the subjects in a manner corresponding with the occupational therapists' clinical impressions for four of six subjects. For the remaining two subjects, rated as 4 and 5 by the therapists, the test scores resulted in ratings of 5 and 4 respectively.

Interobserver agreement determined for three observers timing 88 individual tasks was .93.

One of the C5 quadriplegic subjects tested was also the first subject in the collaborative study to evaluate the efficacy of the FNS orthosis. This individual has grade 3 wrist extensor strength and has performed 13 assessments of prehensile ability over a 13 month period in a single case ABAB design. Three baseline assessments served to establish the subject's usual function prior to functional use of the FNS orthosis. The next five assessments were performed over a five month period of FNS orthosis use. Three repeat baseline assessments were performed during a second baseline period and finally, the subject returned to use of the orthosis.

For each pick-up task, the subject's performance in the midline at desk height was most efficient using bilateral prehension. Unilateral prehension of small, lightweight objects such as cylinders or blocks was initially less efficient without the FNS orthosis but patient performance without the system improved during the course of the study. Although initially unable to prehend a 750 gm cylinder with unilateral prehension without the FNS orthosis, the subject also mastered this task after repeated test performances. In contrast, prehensile tasks accompanied by reaching with heavy objects (book) or reaching to place an object (quarter) in a telephone coin slot were performed consistently better using the FNS orthosis. The subject was unable to achieve these tasks in 60 seconds without the FNS orthosis.

During the functional assessments a significant delay was noted from the time of activation of the FNS system until readiness to prehend an object. The mean delay based on 10 trials was 5.1 ± 0.3 sec.

DISCUSSION AND CONCLUSIONS

The delay in accessing control of prehension when using the FNS orthosis may have contributed to the less favorable comparison of the FNS orthosis versus bimanual prehension. However, the efficiency of bimanual prehension for individuals with C5 quadriplegia is of limited functional application. This pattern is not available during reaching tasks when the individual must hook with one arm to stabilize the trunk. The results of this functional test have been of value in demonstrating the advantage of the FNS orthosis in prehensile tasks which require reaching as a prerequisite and in highlighting a control parameter which may be altered to enhance function.

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ACKNOWLEDGEMENTS

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STANDING BY A COMBINED ORTHOTIC/ELECTRICAL STIMULATION SYSTEM IN THORACIC PARAPLEGIA

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INTRODUCTION

Standing in an upright posture following thoracic or lumbar spinal cord injury has traditionally been accomplished by one of two techniques: bracing or standing frames. Both of these techniques rely on external mechanical support to maintain posture. Functional neuromuscular stimulation (FNS) has been explored in many laboratories as a potential method of achieving standing (and sometimes walking) in a select group of paraplegic individuals [1]. There are problems associated with both external mechanical support techniques and with FNS. Most rehabilitation professionals agree that room for improvement exists in efforts to restore standing.

There have been some attempts to improve technology for mobilizing the spinal cord injured individual by combining FNS and external mechanical support techniques. The rationale for such an approach is that it may be possible to use the positive aspects of each method while eliminating the negative aspects of each method. For example, a frequently cited problem with braces is their weight. A frequently cited problem with FNS is muscle fatigue and the danger of a fall. This study focused on one potential protocol for producing standing using a hybrid system consisting of a unilateral knee-ankle-foot orthosis (KAFOs) and a single channel electrical stimulator.

The motivation for this protocol is the finding of Hussey and Stauffer [3] that patients with incomplete injuries (one leg paralyzed, one leg partially functional) using unilateral KAFO and AFO do much better in terms of their mobility than the bilateral KAFOs user. The hypothesis of the present study was that select patients presently using bilateral KAFOs could be trained to use a unilateral KAFO and single channel stimulator for standing.

METHODS

Three patients participated in this pilot study. Their characteristics are summarized in table 1. All patients had been prescribed KAFOs, were trained in their use for ambulation, and used them on a regular basis. All patients had also been trained to stand using FNS alone (bilateral stimulation of the quadriceps). The FNS standing protocol has been described elsewhere [1].

NR	AGE	SEX	LEVEL	ETIOLOGY	DATE INJ
1	39	M	T5	GSW	11/80
2	25	M	T6	GSW	2/85
3	28	M	T3	MVA	3/81

TABLE 1: CHARACTERISTICS OF PATIENTS

Each patient used the KAFOs they had been prescribed. These were either of the Scott Craig or Standard Droplock design. The stimulator used was a single channel version of the two channel FNS standing stimulator the subjects were familiar with. The unit was operated with a single push button to toggle between standing up and sitting down. After pressing the posture change button, a two second delay occurred, an audible warning sounded, and the stimulation either ramped up to a preset level or down to zero. This allowed the subject to make an easy transition between the sitting and standing postures. Two techniques for standing up were used which differed in the initial placement of the legs. In the first case, the braced leg was fully extended and locked at the knee prior to standing. In the second case, both legs were placed identically, with the knees bent and the ankles directly under the buttocks, as shown in figure 1.

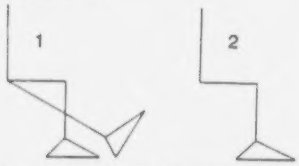

FIGURE 1: INITIAL PLACEMENT OF LEGS

The issues of postural stability and balance are important in this protocol. The ability of most paraplegic individuals to maintain their balance while standing is limited [2]. This ability will be further taxed if the individual attempts to stand primarily on one leg.

RESULTS

A sequence of photographs is shown below to demonstrate the ability of a subject to perform the maneuver (see timer for sequence). The first technique was found to be most acceptable to all subjects. This was because the existing locks at the knee would not reliably engage without one of the spotters manually pushing the brace into full extension. This might be eliminated by a different locking mechanism.

DISCUSSION

The results of this study indicate that this protocol has the potential to be successful in some paraplegic individuals. Acceptance can only be determined by further study. It should be emphasized that each paraplegic patient may have different goals in attempting to stand. They may desire to stand for medical, functional, or psychological benefits. It is therefore important that as many different alternatives for standing be available to a patient. This will allow each patient freedom to choose the techniques best suited for themself.

ACKNOWLEDGMENTS

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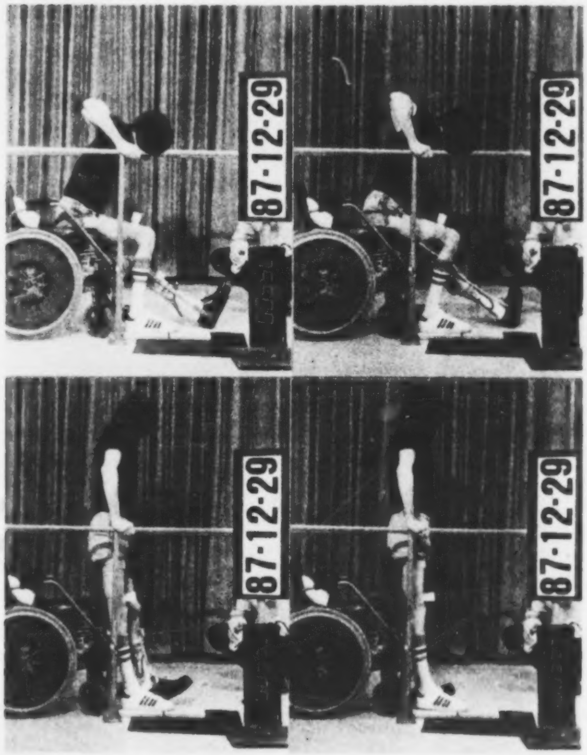

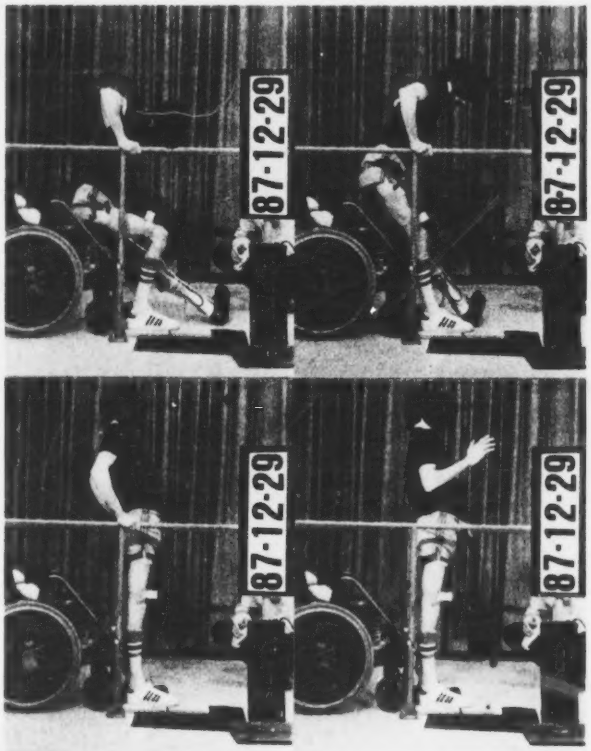

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DESIGN CONSIDERATIONS FOR A PRACTICAL FUNCTIONAL ELECTRICAL STIMULATION (FNS) SYSTEM FOR RESTORING GAIT IN THE PARALYZED PERSON

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ABSTRACT

A percutaneous functional neuromuscular stimulation (FNS) system is undergoing development for restoring ambulatory function in spinal-cord injured people with lesions between T-4 and T-11. Limitations of the current system are electrode failure, muscle fatigue, cumbersome external hardware, an inefficient user/machine interface and lack of closed-loop control of stimulation. Transforming this experimental system into a practical FNS system requires achieving acceptable levels of safety, reliability, function, metabolic energy requirement, ease of use, cosmesis and cost. The authors believe this can be accomplished eventually with development of implantable stimulators, totally implantable electrodes, intimate command devices with tactile feedback, and closed-loop control of muscle stimulation.

INTRODUCTION

The restoration of gait in individuals with upper motor neuron lesions, including stroke, head injury and partial and complete paralysis, is possible because most of these patients have intact nerves below their level of injury which can be stimulated to provide muscle contractions. In 1980 the authors began application to the lower extremity of a percutaneous FNS system which had been previously developed for the upper extremity (5). The current system allows stimulation of up to 48 muscles for the performance of functions including standing, walking, climbing and descending stairs. The only restriction on joint motion is a lightweight ankle-foot orthosis which limits motion in the coronal plane to prevent inversion of the ankle (4).

The current system for walking is used only in the laboratory under supervision of the research staff. This is necessary because safety, reliability, function, metabolic energy requirement, ease of use, and cosmesis are not yet at acceptable levels for a clinically deployable system.

SAFETY AND RELIABILITY

Stimulation levels are always within the safe limits for electrical stimulation of muscle (3) (constant amplitude 20mA, pulse width modulated from 0 to 150 microseconds and a frequency of 15 to 50 Herz). The breakage and movement reliability of the percutaneous electrodes has been significantly improved in the past year through a redesign of the winding to include a core of 5-0 prolene. Development of improved electrode anchors is underway.

Current risks associated with using our FNS system are electrical burns and bone fractures. Although the stimulators have been redesigned to reduce the chance of an electrical burn due to continuous direct current in the event of an electronic component failure, reliability still needs to be improved with the addition of new connectors to the percutaneous electrodes. Following a modification of the AFO to allow some eversion, there have been no fractures. Future plans for the hardware include reduced size and reduced complexity of use.

FUNCTION

Current maximal functional levels of the system are: continuous standing for 60 minutes, fast walking at a speed of .9 m/sec for 20 meters, walking 465 m at a speed of .5 m/sec. In addition some subjects are able to climb and descend steps and walk on ramps of 10 degrees slope.

To be acceptable to the typical user the system will have to provide the following functions: continuous standing for an hour, fast walking at a speed between 1.0 and 1.5 m/sec for 150 meters, walking 2000 meters at 1.0 m/sec, getting up from a low chair, getting up from a fall, walking on ramps and uneven surfaces, negotiating steps and escalators, exercise and recreational activities, and maneuvering in small spaces using crutches.

METABOLIC ENERGY REQUIREMENT

The current system uses 3 times the normal energy requirement for walking at a speed of .56 m/sec and 3.2 times the normal energy requriement for standing (2). As an open-loop system, with no feedback control of stimulation levels, the current system must stimulate muscles at higher (but still safe) levels than necessary, in order to provide the needed margin of safety to deal with muscle fatigue or changes in the environment. Closed-loop or feedback control must be developed to permit automatic adjustment of stimulation levels to sufficient but not excessive levels. Necessary for the implementation of closed-loop control are position and pressure sensors to provide the stimulator with joint angle and weight placement information.

We expect the reductions in stimulation levels achieved by introduction of closed-loop control to bring energy requirements to a level below 50% of the maximum aerobic capacity of the user. We have been able to show a significant reduction in standing energy cost, from 3.2 to 2.0 times normal, when manually controlling the level of stimulation required to prevent knee collapse (2).

COSMESIS AND EASE OF USE

The current system has connecting wires which join the percutaneous electrodes, six surface electrodes (for trunk stimulation), and the footswitches to the portable muscle stimulator, a unit which measures 18 cm x 14 cm x 7 cm and weighs 1230 grams (320 gm of batteries). Push-button switches mounted on a ring and joined by a cable to the stimulator, give the user control over the stimulator. The user's control of the stimulator can be slow when functional transitions - such as changing from walking to ascending stairs - are needed. Users rely on a liquid crystal display for visual confirmation of the stimulator status. To shorten and simplify the selection of functions we are developing a joystick-type control which utilizes the available precise movements of the thumb as a command source, thus providing an intimate control for users with normal hand dexterity and tactile sensation.

Implantation of the stimulator and total implantation of electrodes are planned in order to improve both cosmesis and ease of use. Both control signals and power will be sent through the intact skin by radio frequency transmission as in the 8-channel implanted system (6). The first lower extremity system will use a similar device to provide function for a partially paralyzed individual; systems requiring more than 8 channels will be developed for more severely impaired individuals. Before surgical implantation a percutaneous trial system will be tested on each subject.

Acceptance of an orthotic device depends in large part on its appearance. With the stimulator and electrodes implanted, the external portion of our future sytem will consist only of AFO's and a belt containing the computer-controller, antennae and batteries. Miniaturization of the external controller with hybridization of electronic circuitry will provide a partial solution to the problem of bulkiness.

While percutaneous systems are still in use, the cables connecting electrodes and sensors to the stimulator will be incorporated in a stretch garment, thus simplifying donning and doffing and improving cosmesis.

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ELECTRICAL STIMULATION OF HIP FLEXORS FOR WALKING IN PARALYZED INDIVIDUALS

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INTRODUCTION

Strong reproducible hip flexion is necessary to provide a paralyzed individual with a cosmetically appealing and energy-efficient reciprocal gait. In the past, hip flexion for walking has been induced by peroneal nerve stimulation to induce a withdrawal flexion reflex (1) but this method was slow and unreliable. Our current approach to attaining hip flexion for both walking and stair climbing in paralyzed individuals involves stimulation of hip flexor muscles using percutaneous electrodes (2). In this paper, we report our experience with electrical stimulation of hip flexor muscles in paralyzed individuals.

METHODS

Fourteen subjects with hip flexion deficits resulting from upper motor neuron lesions were included in this study over the past eight years. The deficits were due to stroke, head injury, transverse myelitis, and partial or complete spinal cord injuries. The subjects were implanted with percutaneous intramuscular electrodes in at least one of the hip flexors: iliopsoas, rectus femoris, sartorius, tensor fasciae latae, gracilis and adductor longus (3). Rectus femoris was recruited together with other quadriceps muscles with a single electrode. After implantation the muscles were electrically exercised and included in the subjects' stimulation patterns for walking.

Manual strength testing and electrode impedance measurements were done weekly. The individual muscle function was observed and recorded on video tape while the subject was standing using electrical stimulation. This was done both with the knee fixed in extension with electrical stimulation and with the knee free to move. A two-second burst of pulses was used to produce hip flexion. In three of the subjects hip flexor strength was measured with a Cybex II dynamometer with the subject in a supine position. The pelvis was stabilized with a strap. In addition, the effect on hip flexion of transcutaneous stimulation of the quadratus lumborum and rectus abdominis was examined. Measurements were made isometrically at different hip angles with the knee in extension provided by stimulation of the vastus medialis, vastus lateralis and vastus intermedius muscles. In addition, the moments of the sartorius, tensor fasciae latae and gracilis at the knee were measured at different hip angles. Stimulation parameters were constant current biphasic pulses of 20 mA in amplitude, with 150 microseconds pulse width at a frequency of 50 Hz.

RESULTS

A total of 318 electrodes were implanted in hip flexors of the 14 subjects, 143 in sartorius, 90 in tensor fasciae latae, 52 in gracilis, 32 in iliopsoas and one in adductor longus. Of all electrodes implanted 92 are still active. Others were removed because they moved away from the motor point and no longer produced adequate contractions or because the electrode broke and exhibited high electrical impedance. The average life time of an active electrode was 94 weeks.

Gross observation of muscle function during one-legged standing showed sartorius to produce flexion, abduction and external rotation at the hip and flexion at the knee. Maxima of 40 and 70 degrees of hip and knee flexion respectively were observed. Tensor fasciae latae produced flexion, abduction and internal rotation at the hip. Gracilis produced a similar degree of hip flexion (40 degrees) but considerably more knee flexion (95 degrees) than sartorius. It was also a strong adductor of the thigh. A combination of sartorius, tensor fasciae latae and gracilis produced about 50 degrees of hip flexion and 110 degrees of knee flexion. Iliopsoas produced up to 45 degrees of hip flexion.

Isometric hip flexion moment with the knee fixed in extension decreased as the hip flexion angle increased (Fig 1). Gracilis produced a hip extension moment at a hip flexion angle of 40 degrees or more. Adductor longus produced hip flexion moments at positions up to 30 degrees of hip flexion. Stimulation of quadratus lumborum and rectus abdominis had a significantly larger effect on the amount of hip flexion moment with increase in hip flexion angle.

Using these data we were able to achieve sit-ups in a paraplegic subject with complete spinal cord injury at the level T8/9.
The isometric knee flexion moment of sartorius and gracilis showed an increse as knee and hip flexion increased (Fig 2). Tensor fasciae latae produced no moment at the knee.

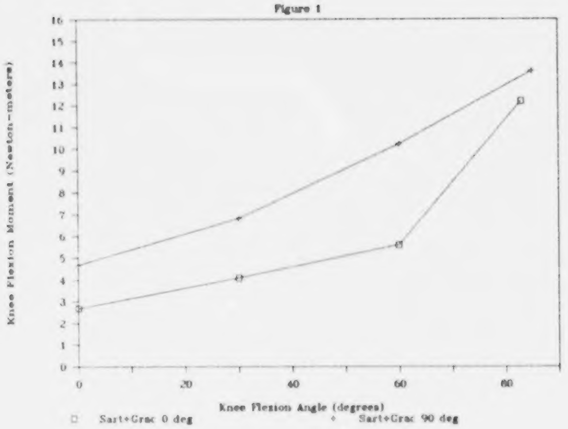

Figure 1

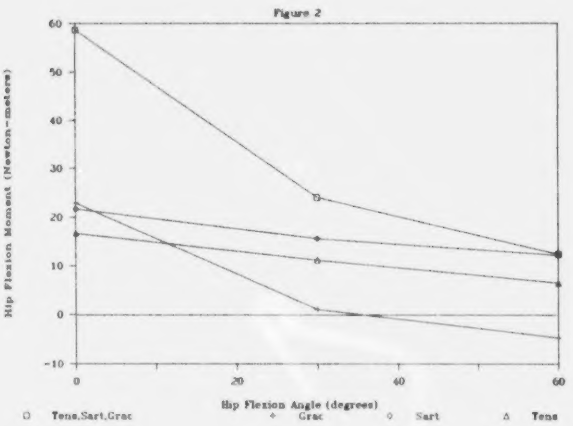

Figure 2

DISCUSSION

Our data on individual muscle action is in general agreement with previously published results. Gracilis was noted before as an extensor of the thigh but only through electromyographic studies (4,5). This study also suggests that only a limited degree of hip flexion can be achieved with tensor, sartorius and gracilis. The addition of either iliopsoas, rectus femoris and adductor longus or all of these together with abdominals is necessary to achieve a normal range of hip flexion. In our functional electrical stimulation system for walking in paraplegic people we deliver a quick burst of stimulation to the whole quadriceps to recruit rectus femoris in order to achieve additional hip flexion during stair climbing and to swing the leg forward.

CONCLUSIONS

The hip flexion moments of tensor fasciae latae, sartorius and gracilis decrease with an increase in hip flexion angle and the gracilis becomes an extensor. The effect of rectus abdominis increases with increased hip flexion angle. Sartorius and gracilis produce moments at the knee which increase with both knee and hip flexion angle.

ACKNOWLEDGMENTS

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A MULTIPROCESSOR-BASED APPROACH TO FLEXIBLE HANDLING OF STIMULUS WAVEFORM PARAMETERS IN A FUNCTIONAL NEUROMUSCULAR STIMULATION SYSTEM

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ABSTRACT

Laboratory instrumentation systems for the research and development of multi-channel functional neuromuscular stimulation (FNS) orthoses generally utilize a computer to manage both the command control processing and the coordination and generation of stimulus waveform parameters. We have found that the efficiency and flexibility of a computer-based FNS system is greatly enhanced when a separate microprocessor is employed to handle the specific task of stimulus waveform coordination and generation. This technique decreases the demands on the control processor, making its computing resources available for more complex processing tasks.

INTRODUCTION

Functional neuromuscular stimulation (FNS) has been used to provide control of upper and lower extremity motor function and rudimentary sensibility in spinal cord injured persons. The basic FNS system handles two tasks: input and output processing. Input processing tasks consist of user command or control signal processing. Output processing includes the coordination and generation of electrical stimuli.

In a single processor system, the amount of computing time available for input processing is limited by the overhead incurred in the output processing computations. For a simple laboratory multi-channel FNS system, a single processor was found to be adequate to control both input and output tasks [1]. However, for more complex systems a single processor would place limits on the number of stimulus channels or on the complexity of the control signal processing algorithms available to the user. Such constraints are significantly reduced if a separate microprocessor is employed to take over the real-time intensive tasks involved in stimulus waveform generation.

With a design goal of minimizing overhead on the input processor, we have designed both laboratory and portable FNS systems [2] in multi-processor, modular configurations utilizing input/output distributed task processing. Typically, the output processor performs the real-time sequencing and stimulus waveform parameter modulation necessary for the generation of electrical stimuli. A description and discussion of one such multiprocessor system used in our laboratories follows.

SYSTEM DESCRIPTION

The basic components of our FNS system are shown in Figure 1. In this system, the input processor controls the tasks of movement planning and command processing. The output processor or Stimulus Waveform Parameter Modulator (SWPM) performs coordination and regulation of stimulus generation by the modulation of stimulus waveform parameters. The two processors communicate over an asynchronous, interrupt driven, bidirectional parallel digital interface.

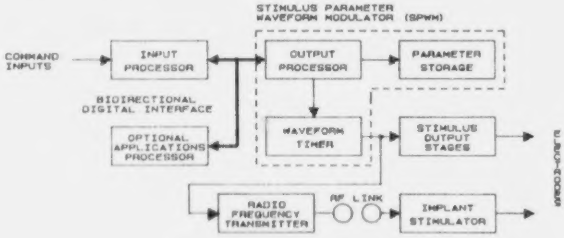
STIMULUS PARAMETER WAVEFORM MODULATOR (SPWM)
COMMAND INPUTS
INPUT PROCESSOR
OUTPUT PROCESSOR
PARAMETER STORAGE
BIDIRECTIONAL DIGITAL INTERFACE
OPTIONAL APPLICATIONS PROCESSOR
WAVEFORM TIMER
STIMULUS OUTPUT STAGES
ELECTRODES
RADIO FREQUENCY TRANSMITTER
RF LINK
IMPLANT STIMULATOR

Figure 1. FNS system components.

The SWPM includes random-access memory for waveform parameter storage. It employs an external timer to generate stimulus waveform timing signals for use in our percutaneous system and can also generate the radio frequency control signals for our implantable stimulator unit [3].

The stimulus waveform type typically implemented in our percutaneous or implantable FNS systems is a biphasic, capacitively coupled current waveform (Figure 2). Five parameters are controlled on a real time basis by the SPWM: pulse duration, interphase delay, charge recovery duration, stimulus amplitude, and stimulus period.

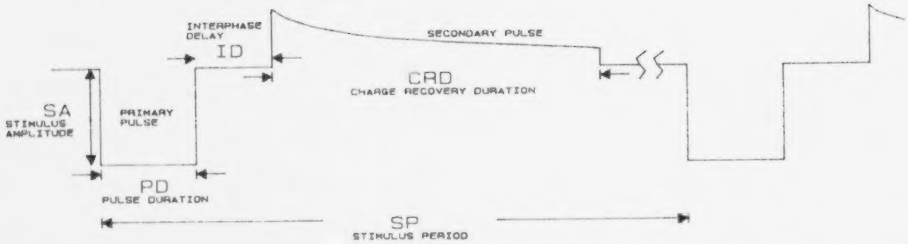

Figure 2. Stimulus current waveform and associated parameters. Typical values: SA=20 ma. PD=100 μs. ID=50 μs. CRD=2 ms. SP=80 ms.

SYSTEM OPERATION

Operation of the current FNS system is similar to that of an earlier laboratory version [1]. The user runs a software application program which specifies the relationships between stimulus waveform parameters and various control signals. These relationships are stored in tables, indexed by a control signal value, and downloaded into the memory of the SWPM. The input processor does not need to store this information and the tables can be updated at any time.

The user specifies various operating modes to the SWPM by the transfer of simple command and data words from the input processor. Operating modes include percutaneous or implant operation and static or interactive operation. In the interactive mode the stimulus period can be controlled on a pulse by pulse basis by the input processor.

Under static operation, the input processor presets the SWPM by transmitting initial control values, active channel information, and stimulus waveform parameter tables. After the preset procedure is completed, the input processor need only communicate such commands to the SWPM as initiate stimulation, halt stimulation, and update a particular control value. The SWPM then produces the programmed stimulus output without any further intervention. In this mode of operation the overhead on the input processor is significantly reduced and it is free to perform more complex command/control processing tasks.

DISCUSSION

The reduction of overhead achieved with this design approach depends on the choice of processors, program efficiency, and the complexity of the stimulus patterns. For example, the overhead due to simple input processing in our earlier laboratory FNS system was 58% [1]. At an additional overhead for output processing of typically 4% per independent stimulus channel, this single processor system could never control more than ten channels at one time. Inclusion of the SWPM in the system eliminates the output processing overhead on the input processor, replacing it with a small (<5%) communication overhead. At a 76% output processing overhead, the SWPM can control 16 independent stimulus channels and handle 1000 communication transfers/second.

This design approach has also contributed to increasing the modularity of our FNS systems and has made transfer of technology for application specific projects easier. We feel that the distributed task processing approach can be applied to evaluative tasks such as long term monitoring and data collection or to intense processing tasks such as the closed loop control of stimulation.

ACKNOWLEDGEMENTS

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A MULTICHANNEL STIMULATOR FOR FNS APPLICATIONS

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INTRODUCTION

Some specialized applications of functional neuromuscular stimulation (FNS) require surface electrode simulation of multiple muscle groups in specific patterns that may be in- or out-of-phase. Such applications include isometric exercise, bicycle ergometer exercise, and pulsed contractions of lower extremity muscles to activate the venous muscle pump. In designing a multichannel stimulator which utilizes a single high voltage power supply in the output circuitry, a problem has been to achieve complete isolation between the channels. Any common electrode configuration tends to cause unwanted stimulation. The purpose of this project was to design a multichannel stimulator for FNS applications that uses a single high voltage power supply and provides complete independence between the outputs of the channels.

METHODS

The schematic diagram of the multichannel electrical stimulator is given in figure 1. Stimulator output consists of square wave pulses of 0.3 msec in duration at a frequency of 35 Hz. Pulse amplitude can be set from 0 to 200 volts across a 1,000 ohm resistive load. Our version of the stimulator was constructed for 8-channels. However, it can be constructed for as many channels as desired by altering the number of drive/output circuits incorporated. For 8-channels, solid state components include two CMOS 4011 quad 2-input NAND gates (U1, U4), a CMOS 4528 dual monostable multivibrator (U2), a CMOS 4017 decade counter (U3), four CMOS 4081 quad 2-input AND gates (e.g. U5, U6), two CMOS 4066 quad bilateral switch (e.g. U7), an LM-324 quad operational amplifier, eight NPN drive transistors (Q1, Q3; NTE-287), and eight pair of complementary NPN-PNP high voltage output transistors (Q2, Q4; NTE-396, NTE-397). Three series connected 1.5-volt batteries power the drive circuitry, whereas three series connected 67.5-volt batteries provide the high voltage output to the skin surface electrodes. Current drain is about 1-2 milliamperes from the batteries (depending upon the stimulator output level).

Circuit operation. U1A and B are configured as a square wave oscillator whose output pulse frequency is set at 350 Hz (10 times the stimulator output frequency of 35 Hz) U1C disables the clock for about 20-sec when the stimulator is turned on to prevent any unwanted output pulses. U1D in conjunction with an LED indicates the the stimulator disabled state. Clock pulses trigger the inputs of U2 and U3. U2 sets the pulse width to about 0.3 msec, whereas U3 provides 10 independent sequenced outputs (35 Hz each). Outputs of U2 and U3 drive AND gate (U5, etc.) inputs, and the AND gate outputs drive the control pins of solid switches (U7, etc.). This converts the incoming DC drive voltage from a continuous to a pulsatile signal for switching the stimulator output transistors. Drive voltage for each channel is derived from the output of an AND gate (U6, etc.), and the level is set by a 10-turn 5K potentiometer. Drive level is indicated by a meter (switched to each channel by S17) that is driven by U8A. The AND gates may be controlled by one of three methods: 1- depressing a momentary switch (S9, etc.), 2- by an internal oscillator (U4) which provides on-off pulses at a duration (e.g. 2-sec) that is set by the 1-meg control, S1-S8 allow for synchronous/asynchronous patterns of stimulator channel output, and 3- external inputs (+4.5-volts at J1-J8, and S1-S8 in the proper position) from a computer to control output of the stimulator channels in accordance with a program. Transistors Q1 and Q2 are linear amplifiers that are driven by the DC pulses from the analog switches. The collector of Q2 is connected to one of the skin surface electrodes (cathode). As Q2 conducts, this electrode comes closer to ground potential. Transistors Q3 and Q4 are used to switch the other electrode (anode). The collector of Q4 is connected to this electrode, whereas its emitter is connected to the positive high voltage. Thus, when Q4 conducts, its electrode is essentially connected to the positive high voltage. This creates a current flow through the tissues which can induce muscle contraction. Q3 and Q4 switching is controlled by an AND gate (U5, etc.). Since both electrodes of each channel are switched, there is complete isolation between the channels, and improved safety in the event of output transistor breakdown.

RESULTS AND DISCUSSION

During operation, electrodes are placed over motor points of the of the muscle groups to be stimulated. Contraction level is set for each channel by depressing the appropriate momentary switch (S9-S16) while adjusting the 10-turn potentiometer. When the desired contraction levels are achieved, repetitive synchronous or asynchronous contraction patterns of muscle groups may be obtained by selecting the position of S1-S8. With S1-S8 in the external position, external control (e.g. computer) of stimulator output can be obtained. Although we consider this electrical stimulator to be relatively safe, there are, of course, still risks of limb (and other) injury for research subjects. Therefore, appropriate precautions must be taken when using this (or any other) electrical stimulator.

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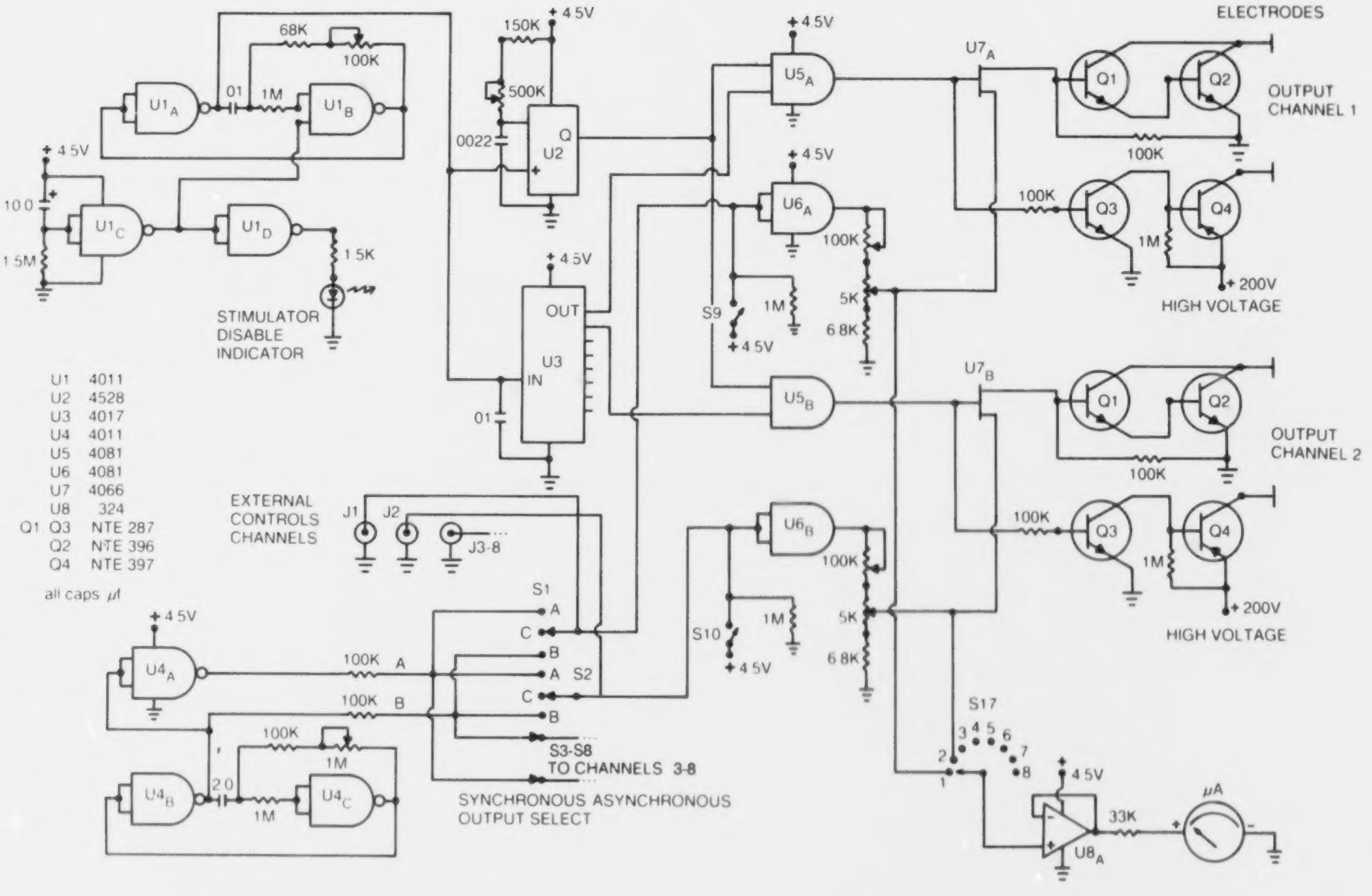
ELECTRODES
OUTPUT CHANNEL 1
OUTPUT CHANNEL 2
+ 200V
HIGH VOLTAGE
+ 4.5V
68K
100K
150K
500K
.01
1M
.0022
U1A
U1B
U1C
U1D
U2
Q
U3
IN
OUT
U5A
U5B
U6A
U6B
U7A
U7B
Q1
Q2
Q3
Q4
10.0
1.5M
1.5K
STIMULATOR DISABLE INDICATOR
U1 4011
U2 4528
U3 4017
U4 4011
U5 4081
U6 4081
U7 4066
U8 324
Q1 Q3 NTE 287
Q2 NTE 396
Q4 NTE 397
all caps μf
EXTERNAL CONTROLS CHANNELS
J1
J2
J3-8
S1
S2
A
B
C
S9
S10
5K
6.8K
U4A
U4B
U4C
2.0
S3-S8 TO CHANNELS 3-8
SYNCHRONOUS ASYNCHRONOUS OUTPUT SELECT
S17
1 2 3 4 5 6 7 8
33K
U8A
μA

Figure 1. Schematic diagram of the multichannel electrical stimulator for functional electrical stimulation applications.

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CONTROL OF PARAPLEGIC GAIT BY DETECTION OF DISCRETE EVENTS

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INTRODUCTION

Our functional electrical stimulation system for restoration of ambulatory functions in paraplegic individuals has evolved to the point where most major innervated paralyzed muscles can be stimulated. Contractions of different muscles can be coordinated to produce movements which may be used to accomplish activities of daily living. This orthosis differs form those developed by others in that all major paralyzed muscles in a subject are under control of stimulation and that no joint motions are directed or restricted by external braces. The coordination and synchronization of muscle acivities with kinematics of the body has been done in the past by trial and error based on their normal activity during gait. As the speed of walking increases this method of synchronization becomes more difficult and small changes in the stimulation pattern can have pronounced effect on kinematics and mechanical efficiency of the gait.

METHODS

Paraplegic subjects with complete spinal cord transection at levels between T4 and T11 were included in this study. They were implanted with percutaneous intramuscular electrodes in muscles controlling hip, knee and ankle (1). At the hip gluteus maximus, posterior portion of adductor magnus, and at least one head of hamstrings were implanted for hip extension. Gluteus medius was implanted for hip abduction. Tensor fasciae latae, sartorius, gracilis and iliopsoas were implanted for hip flexion. Knee extension was provided by vastus medialis, vastus lateralis and vastus intermedius. A balanced dorsiflexion was produced by stimulation through one electrode which recruited both tibialis anterior and peroneals. Plantar flexion was also recruited with one electrode stimulating both gastrocnemius and soleus. Surface stimulation was used for trunk control. Trunk extension was produced by stimulation of erector spinae and sideways bending by stimulation of quadratus lumborum. Hip extension was suplemented by surface stimulation of hamstrings and posterior portion of adductor magnus, both of which were activated with a single electrode.

A 48-channel laboratory-based electrical stimulation system was used for delivering both surface and percutaneous stimulation. Up to ten of the channels could be assigned to surface stimulation. The stimulation pulses used for percutaneous stimulation were constant current, biphasic, charge balanced, and 20mA in amplitude. The pulse width was modulated from 0 to 150 microseconds and frequency from 16 to 60 Hz. For surface stimulation amplitude was increased up to 100mA and pulse width up to 255 microseconds. All muscles were not available in each subject and often more than one electrode was used per muscle.

The subject used a joystick and a 2x2 matrix of push-button switches to control the system. The eight-position joystick allowed the subject to select menus of various activities. For example, if standing the subject could walk, go upstairs, go downstairs or sit down by moving the joystick in the respective position and depressing it. After getting into the walk menu the subject could further select walk forward, step to the side, step backward or sit down. The lower two switches in the matrix were GO to activate the selected activity and RETURN to exit the activity and return to previous menu. The upper two switches were used to regulate the speed of progression through the gait cycle. When entering the stimulation pattern for walking the subject could progress through the gait cycle either manually by continuously depressing the GO switch or automatically through detection of discrete events such as foot switch contact or threshold levels of pressure. An insole was instrumented with four force-sensing resistors (FSR) (Interlink Electronics) placed under the heel, first and fifth metatarsals and big toe. A weighted average of pressure on the sensors was used to determine the progression of center of pressure under the foot and compared to the center of pressure as obtained by the force plate (Advanced Mechanical Technology). The amount of weight transfer at heel strike was also related to the amount of pressure on the FSR and and reaching a specified threshold level was used as a discrete event to trigger initiation of weight transfer to the leading leg.

RESULTS AND DISCUSSION

We found foot switches to be too sensitive and position dependent for practical use. However, the center of pressure under the foot obtained from FSR's was a good approximation of the one derived from force plates. Further, the pressure detected during gait of paraplegic subjects was repeatable enough to control gait.

A stimulation pattern was derived from normal electromyographic activity of human walking (2) and modified by trial and error to enable paraplegic subjects to walk at speeds of up to 1m/sec with a rolling walker for support. One subject T8/9 was able to walk with forearm crutches in a two point gait.

The stimulation pattern for walking (Fig 1) is structured into different phases corresponding to the specific tasks of gait (3) which are separated by breakpoints (BP). These include weight acceptance (BP0-1), trunk glide (BP1-3), push (BP3-4), balance assistance (BP4-5), pick up (BP5-7) and reach (BP7-8).

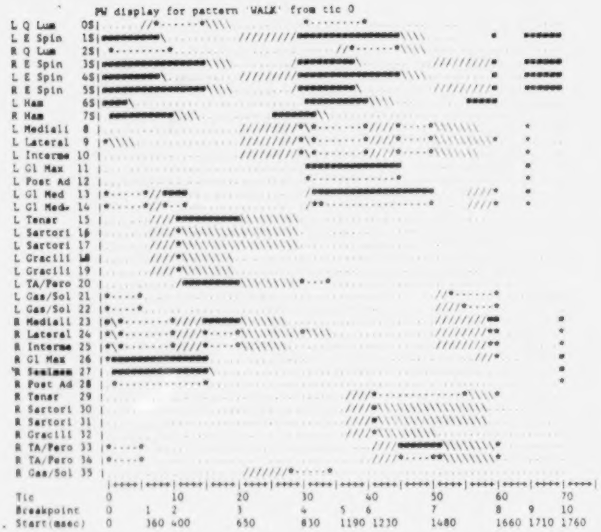
Discrete events that allow progression through the gait cycle are threshold pressure on the FSRs under the left and right heel or the GO push-button switch at breakpoints 0 and 4. An early hand switch trigger before enough weight acceptance occurs, results in early activation of hip extensors bringing the leg backwards to where it was before the swing phase. Further, the failure of initiation of the next task of trunk gliding causes the subject to lose momentum. We found that synchronizing activation of hip extensors based on threshold pressure detection provides better weight transfer to the leading leg and enhances trunk glide task. Activity of ankle dorsiflexors is also timed to this initiation of weight acceptance and prevents slapping of the foot. Allowing for slight knee flexion during weight acceptance and early trunk glide will reduce required elevation of the center of gravity and provide a smoother and more efficient gait.

An important task which we found to be critical and which will require triggering by a discrete event is push. Early activation of plantar flexors will push the body upward and backwards, producing flexion at the hip and preventing the swinging leg from reaching forward. In addition, the momentum gathered during trunk glide will be lost. Center of pressure movement in front of the ankle joint to the forefoot could be used to initiate activation of plantar flexors.

Controlled knee flexion during balance assistance was important in successful weight acceptance by the other limb. With the knee stiff the opposite leg would fall short of the heel strike and swing backward. This resulted in an unstable position with the body moving forward without weight acceptance capability other than on the arms on the walking support.

During pick-up a toe drag often occurs and interferes with forward reach during the swing phase of gait. Planned implantation of a short head of biceps femoris is expected to correct this problem.

Two problems are usually observed during reach. First is in the early part of the task where the reaching leg hits the supporting leg, usually due to adduction of the gracilis. This interferes with the swing of the leg resulting in shorter step length and also with the next weight acceptance. Another problem occurs during late reach when the leg swings out and back before heel strike due to lack of co-contraction control at the knee.



CONCLUSIONS

A useful pattern of electrical stimulation for walking of paraplegic subjects can be obtained by trial and error. The problem however is the synchronization of the body kinematics with the pattern. Simple foot pressure measurements can provide useful information about events such as heel strike, toe off, movement of center of pressure in front of the ankle joint, percentage of weight transfer onto the loading foot and specific pressure distribution on the feet. These can be used to improve synchronization of the muscle activities with kinematics of the body and improve the walking of paraplegic subjects.

ACKNOWLEDGEMENTS

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HYBRID FES GAIT ORTHOSIS USING CONTROLLABLE DAMPING ELEMENTS

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Abstract

This paper describes a novel approach to control electrically stimulated muscle output with application to FES gait. The output of electrically stimulated muscle is treated as an unregulated mechanical power source and control is achieved by adding a friction brake to regulate the output. We have built a simulator to assess the efficacy of the brake as a controller.

Introduction

Although considerable progress has been made in using functional electrical stimulation (FES) to restore gait for paraplegics, many obstacles still prevent its everyday use. One of the stumbling blocks is the variation in response of electrically stimulated muscle. For example, stimulation of the quadriceps often results in a very different response when restimulated only minutes later. With such an unpredictable response, it is difficult to select an appropriate program of stimulation which will elicit reproducible gait step after step.

One can view electrically stimulated muscle as a source of unregulated mechanical power. Improved control of limb dynamics can therefore be obtained by adding a regulating element, such as a friction brake, much the same way as a transistor can regulate an electrical power source. In this paper, we present a concept for a hybrid FES orthosis which combines electrical stimulation and lightweight bracing with friction brakes at the joints.

The idea of using bracing for paraplegic walking is not new. High metabolic energy costs as well as poor functional mobility and poor cosmesis have, however, prevented its wide acceptance with most patients eventually preferring a wheelchair over long legged bracing (1). Several research groups have combined bracing with FES. For example, at Wright State University, FES is used with the LSU brace (2). Gait is achieved by using the brace to lock the knee and ankle joints and electrical stimulation to reciprocally activate the hip extensors which are coupled to the contralateral hip flexors through cables. The bracing does provide added support and stability, but locking the knee joint limits the system to non-physiologic limb trajectories and therefore inefficient gait. Also, at the Zotovic Rehabilitation Center in Yugoslovia, Popovic uses a knee brace which incoorperates a DC motor at the joint for active assistance of FES gait (3). Although Popovic is able to demonstrate improvement in gait, the small motors require a high transmission ratio which may hinder the free swinging capability of the brace.

Our proposed combination of brace/brake/FES attempts to minimize bracing and to realize the full potential of FES. **Joints are not locked, but rather controlled continuously through the full braking range.** Further, new lightweight bracing materials can provide stability while keeping weight to a minimum. This combination should provide better control of muscle output and of FES gait.

The brake has other benefits aside from that of a regulator of muscle output. In an FES system, co-contraction can be used to improve control of limb positioning (4), however, this comes at high metabolic energy costs and may cause greater muscle fatigue. In many cases, however, the brake can replace the antagonist muscle by serving as a damping load against which the antagonist can pull. Brakes can also be used effectively in purely dissipative activities such as a controlled transition to sitting. Finally, paraplegic standing for extended periods of time is currently accomplished by maximally stimulating the quadriceps to lock the knee (5). Failure occurs when the quadriceps tires. The brake can be used in place of the quadriceps and can allow a paraplegic to remain standing for a much longer time period.

To evaluate the concept of the braked hybrid FES gait system, we have built a laboratory simulator with which we can explore control of the knee joint. We feel this an important step before embarking on the design of a full six degree-of-freedom leg brace.

Hybrid Brace Simulator

The simulator consists of a knee orthosis attached to an inclined bench. The subject sits on the bench with his or her lower leg strapped into the orthosis. The linkages of the orthosis are coupled to a magnetic particle brake via timing belts (Figure 1). A potentiometer, a tachometer and strain gauges are also coupled to the linkages to measure position, velocity and torque about the knee. Surface electrodes are placed to achieve activation of the quadriceps and hamstring muscle groups. An AT&T 6300+ PC controls the stimulator and the particle brake. Strategies for controlling knee joint dynamics can be implemented through simple changes in software. This setup permits testing of both able-bodied and SCI subjects.

Our first experiments using the hybrid brake simulator have the objective of position controlling the knee. We are comparing three control strategies: open-loop FES, closed-loop FES, and closed-loop FES with the brake as a regulator. For each controller, a recruitment curve of stimulus amplitude versus isometric muscle torque is obtained for both the quadriceps and the hamstrings. An inverse recruitment map is created to account for muscle static length-tension relationships and non-linear moment arm. This map is placed in the forward path of each controller.

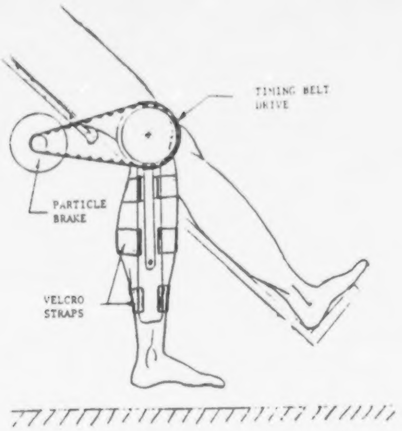

Figure 1 Sketch of the Brake Orthosis Interface

The tracking ability of open-loop FES is assessed for various trajectories. The computer reads in the desired position, finds the corresponding stimulus in the recruitment curve and gives the stimulator the appropriate commands. Performance criteria are based on average position error and the average product of stimulus time and stimulus amplitude (a measure of muscle use). Similar tests are performed with the closed-loop controllers both with and without the brake. To provide a standard of comparison, performance is compared to voluntary tracking.

Conclusions

Preliminary tests performed at the time of this writing show that the brake can be an effective regulator. Minimally, it can provide additional damping to stabilize a closed-loop control system which uses high gains. Further testing is underway to assess the value of the regulator concept and we are also exploring design concepts for a wearable brace. The question of whether or not the benefits of increased control outweigh the decreased cosmesis and increased load to the patient, however, cannot be determined until a complete system is implemented and evaluated.

Acknowledgements

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DEVELOPMENT AND OPERATION OF A LABORATORY ELECTRICAL STIMULATION SYSTEM FOR WALKING IN PARAPLEGIC SUBJECTS

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INTRODUCTION

The portable microprocessor based electronic stimulator has proven to be an essential tool in the application of functional neuromuscular stimulation (FNS) to walking in paraplegic subjects. However, as a development tool the portable stimulator exhibits several limitations, especially in the following areas:

1) Stimulation pattern development.
2) Stimulation program development.
3) Closed loop algorithm development.

This paper describes the design of a non-portable laboratory stimulation system which addresses these limitations while maintaining complete functional compatability with current portable designs.

SYSTEM SPECIFICATION

The first requirement for the lab system was that it implement efficient pattern development. The current version of the portable stimulator at the VA Medical Center Motion Study Laboratory employs a complex assortment of programmable features including: full control of pulsewidth and frequency modulation; variable pattern playback speeds; configurable user menus; jumps to different patterns or pattern sections; and the use of pushbuttons, footswitches and foot pressure transducers to control pattern progression. During the process of tuning the stimulator to achieve an acceptable level of functionality for a particular subject or function, these parameters will be changed many times while the resultant operation is monitored. The length of time required to effect these changes therefore has a profound influence on the efficacy of pattern development. For the current portable stimulator, the limiting step in pattern modifications is the electronic programming of the pattern tables into EPROM, a process requiring at least 20 minutes.

Stimulation program development was likewise limited by the EPROM programming step. Although the stimulation program itself does not undergo changes often, while it is being changed each revision of the program (with appropriate pattern tables) must be loaded into EPROM for testing and debugging.

Although the computing power of the present portable system is easily sufficient to support the present level of open loop functionality, it falls short of the capabilities required by a reasonably complex closed-loop system, especially for algorithm development tasks. Ideally, the lab system design should implement closed-loop control in such a way that it allows straightforward evolution to future portable designs.

Past lab system designs relied on the programming of a large computer to perform the same tasks as the portable stimulator. Given the complexity of the present portable system, this approach would involve an impractical amount of parallel programming on dissimilar CPUs. This leads to the most fundamental specification for the lab system: it must incorporate a portable stimulator as an integral part of its design.

HARDWARE

The laboratory system was based on the current version of the portable stimulator, which is built around a 4 MHz CMOS NEC V40 microprocessor. This processor is object-code compatible with the Intel 8086 processor, directly addresses 1 Mbyte of memory, has a built in 3-channel counter/timer and 8 levels of prioritized interrupts. The portable includes 256K of EPROM for the stimulation program and control tables, 32 Kbyte of battery-backed RAM, 24 channels of digital I/O and 16 channels of A/D input. Decoding is provided for 48 channels of stimulation, 10 surface and 38 intramuscular. User input is derived from 4 digital pushbutton switches and a joystick. Control inputs are also taken from 6 foot switches or 8 force sensing resistors, which provide foot pressure information. Stimulator state information is provided for the user in a 16 character by 2 line LCD display.

The lab system (see figure) was constructed by augmenting the essential features of a portable stimulator with hardware which adds the following capabilities:

1) High speed communication with the lab's minicomputer, a DEC MicroVAX II.
2) Writeable storage for the stimulation program and control tables.
3) Mobility within the lab environment while maintaining electrical connection to the fixed lab system.

VAX communication was achieved through the use of a 2 Kbyte dual port RAM chip, which communicates on one side with the V40 processor and on the other side with a parallel port on the VAX. Auto-incrementing address registers allow rapid filling and emptying of buffers in the dual port RAM from the VAX side, and unused address bits may be used by the VAX to initiate several types of interrupt on the V40. Complete optical isolation is provided between the VAX and the stimulator, which is battery powered.

Writeable storage for the stimulation program and control tables was implemented through the addition of 256K of RAM. Once this RAM is filled by the

VAX it can be used in place of the EPROM as the source for the stimulation program and control tables.

Limited subject mobility using the lab system was provided by splitting the stimulator into a fixed portion and a small portable section, which are then electrically connected by 100 ft of 60-conductor shielded cable. This cable is festooned and allows the user the freedom to walk the length of a 60-foot walkway.

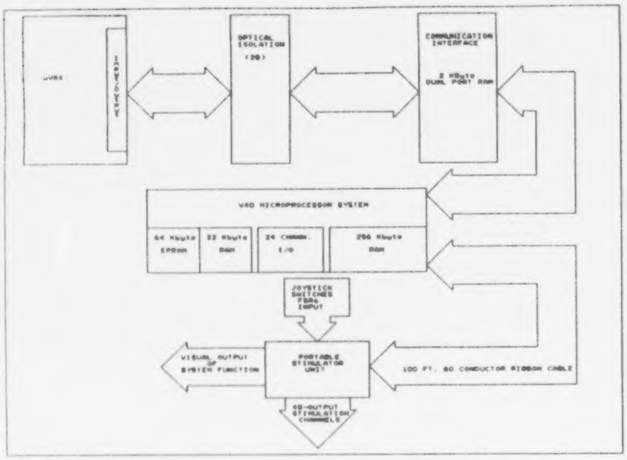
SOFTWARE

The dual port RAM (DPR) chip is used by the system software both as a communication device and as a storage area. Message passing is the primary communication transaction between the VAX and the V40, and two areas of the DPR are set aside as FIFO queues for variable length messages. A larger area is set aside for use as a double buffering area for transfers of large blocks of information, such as the pattern tables. Such transfers are initiated and mediated by messages. Part of the DPR space is also used as a static storage area. This area is especially important for closed-loop operation, when the VAX stores a pulsewidth and frequency table there for use by the V40.

The program stored in the lab system EPROM is a simple program which can communicate with the VAX through the DPR. The VAX can command it to accomplish the following two tasks: 1) Load any area of memory with data provided by the VAX; 2) Execute code starting at any location. To run V40 code on the lab system, the VAX performs the following steps: 1) Use the non-maskable interrupt to restart the lab system; 2) Load code and tables (if necessary); 3) Execute at the code's startup location. Note that the non-maskable interrupt is disabled during active stimulation as a safety feature.

The primary VAX program for stimulation is the pattern editing program. This program allows a user to edit, store and retreive all pattern parameters. The program can use these parameters to construct pattern tables, which may be written to a file and later used to program an EPROM, or dumped directly to the lab system through the DPR. When the tables are dumped to the lab system, the current V40 stimulation program is relocated and dumped as well. The same V40 stimulation program that is programmed into EPROMs for portable use is used by the lab system; there is no possibilty of incompatability.

During closed-loop operation, the VAX can directly control stimulation pulsewidth and frequency by asynchronously modifying the static DPR tables. This control may be exerted on a standalone V40 program for complete closed-loop control, or on a modified portable stimulation program for integrated closed and open loop control.


uVAX
OPTICAL ISOLATION
(2B)
COMMUNICATION INTERFACE
2 Kbyte DUAL PORT RAM
V40 MICROPROCESSOR SYSTEM
64 Kbyte EPROM
32 Kbyte RAM
24 CHANN. I/O
256 Kbyte RAM
JOYSTICK SWITCHES FSRs INPUT
VISUAL OUTPUT OF SYSTEM FUNCTION
PORTABLE STIMULATOR UNIT
100 FT. 60 CONDUCTOR RIBBON CABLE
48-OUTPUT STIMULATION CHANNELS

DISCUSSION

When used as a pattern development system, the lab system can construct pattern tables and dump the tables along with the stimulation program to the V40 in about 15 seconds, as compared to the 20 minutes required for the portable system. This speed has made it practical to make and evaluate many small stimulation pattern changes in a relatively short period of time.

Program development was similarly aided by the turnaround time of the lab system. The lab system is presently used to develop all programs designed to run on the portable stimulator including the portable stimulation program. Since the lab system uses the portable system's software, there is never a time lag or incompatability between the two systems: as new features are implemented for the portable system, they automatically become part of the lab system.

While a fully functional closed-loop control program has not yet been implemented on the VAX, test programs have been written which verify that the VAX can directly control stimulation pulsewidth and frequency in realtime. Both a standalone V40 program and an extended version of the portable stimulator program have been successfully tested.

If closed-loop control proves advantageous and is suitably efficient, portable hardware will be produced to support the appropriate algorithms. By using a DPR chip to interface this hardware to the portable stimulator, the lab system's closed-loop software can be used for closed-loop control without modification.

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A SYSTEMATIC APPROACH TO THE CLINICAL IMPLEMENTATION AND EVALUATION OF A PORTABLE FUNCTIONAL NEUROMUSCULAR STIMULATION HAND GRASP SYSTEM

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ABSTRACT

Functional Neuromuscular Stimulation (FNS) has been shown to be a viable method to provide functional restoration of prehension/release hand grasp for C5 and C6 level spinal cord injury patients. A systematic approach is presented to clinically implement and evaluate a portable FNS hand grasp system. The procedure includes the candidate selection, therapy, system implementation, training, evaluation and follow-up procedures. Implementing the hand grasp system requires a team approach which involves engineers, physicians and therapists.

CANDIDATE SELECTION

A diagram for the overall implementation is shown in Figure 1. The initial evaluation for candidate selection is composed of a physiological, psychological and support mechanism evaluation. This includes a review of the medical history of the patient, patient interviews, diagnostic testing, activities of daily living (ADL) testing, and discussions with the family or support groups. Diagnostic testing includes manual muscle testing, neuromuscular response to electrical stimulation, sensory evaluation and passive and active range of motion. A candidate selection criteria has been derived by our laboratory (Stroh, 1988).

GOAL SETTING AND INTERVENTION

Long and short term goals are discussed and set with the subject. These goals include the specific uses of the hand system as well as overall life or career objectives and how our program fits into those goals. Upon admission into the program, the subject begins physical assessment and intervention to prepare him for the hand system. This effort is directed toward increasing the range of motion of joints, strengthening voluntary muscles and maximizing independence using standard rehabilitation methods.

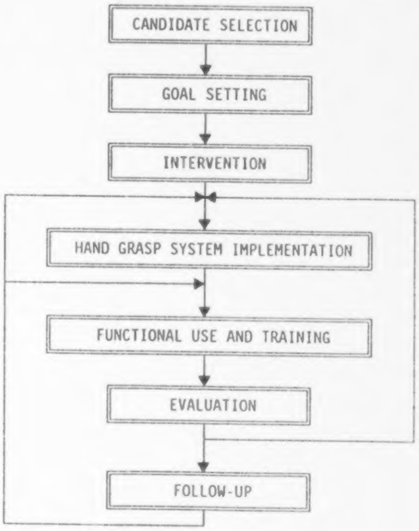

Figure 1. Diagram of system implementation.

SYSTEM IMPLEMENTATION

The actual hand system implementation involves implantation of percutaneous electrodes, coordination of electrode stimulation patterns, evaluation of command/control methods, implementation of electrocutaneous feedback, production of the system hardware and programming of all appropriate parameters into the hardware.

The electrodes are implanted percutaneously using hypodermic needles and a laboratory stimulation system (Thrope, 85). The patient is instructed to discontinue range of motion to the wrist and fingers for a stabilization period of two weeks.

After implantation, stabilization and initial strengthening, an electrode profile is developed, which includes pertinent recruitment characteristics for each electrode (Kilgore, 1988). From the electrode profiles, first draft movement coordination patterns are developed for lateral and palmar prehension grasps. The stimulus parameters are then adjusted interactively until the optimum hand grasp patterns are developed.

The subject is next evaluated for command control methods. The most common method is shoulder position using a chest mounted dual axis proportional joystick transducer.

The subject is then evaluated for electrocutaneous feedback. A traditional sensory evaluation is performed, along with a mapping of the electrocutaneous response. In a sensory intact region, a single subdermal electrode is implanted, which produces a sensory stimulus in response to the state of the hand grasp system and the command output.

The stimulus, control and feedback parameters which have been generated are then programmed into a portable stimulation unit. The portable stimulation units are fabricated in our laboratories, along with the associated transducers, cables and patient interfaces.

TRAINING

Training involves the subject, his family, his support group, engineers and the associated therapists. The goal is to incorporate the hand system into all appropriate areas of ADL. Training areas include donning and doffing the system, operating the system effectively and maintaining the electrode sites, as well as efficient integration of the system into ADL.

EVALUATION

The system is evaluated in four areas: the function of the subject's hand (the physical response to a command input), the subject's ability to produce the desired command signal, his ability to perform tasks, which include or simulate ADL, and the overall reliability of the system, including hardware (Thrope, 1988).

FOLLOW-UP

Follow-up is required for hardware support, maintenance, chronic monitoring of system performance and physiological stability of the system. Once the hand grasp patterns are programmed, they are periodically fine tuned. This procedure may include updating the profile of the individual electrodes, checking for broken electrodes, implanting new electrodes, when necessary, and adjusting the coordination patterns of the electrodes.

Follow-up also includes the visitation of home and worksite, when appropriate, by a rehabilitation engineering/occupational therapy team to determine where adaptive aids could augment the subject's hand system, establish practical goals for the use of his hand system, help overcome barriers to the daily use of his system and increase his level of independence.

Occupational and physical therapy follow-up is required to monitor the long term performance of the system and to maintain adequate physiological characteristics of the subject's hand, including range of motion, and joint mobility. This follow-up also includes functional and performance testing.

Once a subject is proven to be a good user of the percutaneous system, he is evaluated for augmentative surgical intervention and eventually for a totally implanted system. These surgical interventions include tendon transfers to compensate for denervated muscles and imbalanced grasping patterns and thumb IP joint arthrodesis to stabilize the thumb.

ACKNOWLEDGEMENT

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Quantitative Assessment of Object Acquisition and Release using a Neural Prosthetic Hand System with C5 and C6 Quadriplegics

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ABSTRACT

Our laboratory has developed a neural prosthetic hand system using Functional Neuromuscular Stimulation (FNS) that enables C5 and C6 level quadriplegic individuals to control lateral (key-grip) and palmar prehension and release. The individuals use their hand systems to independently perform functional tasks that they cannot perform without the use of the hand system. The ability to manually acquire and use a common object such as a fork or glass without the aid of adaptive equipment greatly enhances a subject's level of independence. We are now able to administer a test that quantifies the ability of a subject to acquire and release a set of objects. The objects vary in mass and geometric configuration with each having a functional analog. This test has enabled our clinical research team to quantitatively evaluate the hand grasp proficiency and consistency of performance. It provides a means to compare a subject's performance with and without the use of the hand system while contrasting these results against other subjects in the program.

INTRODUCTION

An estimate of the effectiveness, consistency, and proficiency of operation of the FNS hand system is necessary in order to determine its usefulness. The overall goal is to develop a functional test that can be administered by clinicians in a repeatable manner within a reasonable amount of time. The information that is obtained from the functional test will be used to gauge how well a person can perform in a real environment and what alterations might be necessary in order to improve the hand system. It must provide both the subject and the clinician clear evidence of the advantage of using or not using the neuroprosthesis to complete certain tasks.

An object acquisition and release test must first be administered prior to the functional testing paradigm to determine a baseline criteria of the hand system performance. The purpose of this test is to assess the ability of C5 and C6 quadriplegics in using an upper extremity neural prosthetic hand system to acquire and release objects with varying geometric configurations and masses.

The evaluator must have a method to assess the minimal acceptable levels of user performance prior to administering training in the use of the neuroprosthesis. There are several system characteristic of the neuroprosthesis that should be evaluated to produce an optimal system configuration. These characteristics include the control parameters, the stimulation parameters, and the integration of control and hand stimulus processes. During each phase of training the evaluator must assume that the subject has a satisfactory hand system, with reasonable control and stimulus parameters, that will enable the subject to accomplish functional tasks in an optimum manner. The evaluation of the utility of the neuroprosthesis is dependent upon the hand system operating correctly. Therefore, the quantitative measurement of object acquisition and release is an important first step towards establishing whether a hand system will enable a person to manipulate functional objects and whether the system is operating sufficiently.

There are many factors that affect the overall functional performance of a subject. Yet the ability to grasp, pickup, and release an object is paramount to using the hand system. Thus, a test has been developed to specifically monitor the capability of the user to acquire and release several types of objects with varying geometric configurations and masses. The test minimizes factors such as balance, proximal musculature, and fatigue and concentrates on the terminal hand grasp and release mechanism.

OBJECT ACQUISITION AND RELEASE TESTING PROCEDURE

The assessment consists of six separate tasks (Table I.) Three tasks are assigned to the lateral grasp and three for the palmar grasp. The level of skill in accomplishing each task is defined as simple, moderate, and difficult depending upon the size and weight of the object. Each task has a functional analog to provide a measure of the effectiveness in applying the hand system in a real environment.

An initial pre-test period is used to determine whether a subject can complete a task. The subject is given as much time as he requires and is instructed to tell the evaluator whether he cannot complete the task. The tasks are performed with and without the use of the neuroprosthesis . Only the tasks that can be performed successfully during the pre-test period are applied during the actual test session.

The subject is asked to acquire, move, and release each object as many times as possible within 30 seconds. The subject is given at least 30 seconds to rest between each task to minimize fatigue. Each time a task is presented to the subject it is performed with and without the use of the neuroprosthesis (unless he could not accomplish this during the pre-test period). The tasks are randomized so that the subject is not influenced by task ordering. The subject is instructed to use a particular grasp (lateral or palmar). The subject is also instructed to acquire, move, and release the object in a specific orientation. These constraints are necessary to avoid inconsistencies which do not require an active grasp to complete the task. The subject performs the group of tasks 5 times in succession.

RESULTS

We have presently evaluated nine subjects. As demonstrated in Table II, users of the FNS hand systems can acquire heavier or more difficult to manipulate objects in greater average numbers per test session and with a greater success rate (attempting to acquire an object / completions) by using the FNS hand system. Also, subjects using the neuroprosthesis will typically outperform subjects who are using their non-surgically altered tenodesis wrist extension when comparing the results of the more difficult tasks.

CONCLUSION

Although these results are preliminary, they are consistent with the qualitative results that have been obtained by analyzing 27 FNS neuroprosthetic hand system users over the course of the program. Almost all subjects have been able to obtain a level of proficiency that enables them to manipulate objects that they normally would be unable to perform without the aid of either an orthosis or external assistance.

The object acquisition and release test provides a measure of hand performance that enables us to determine the effectiveness of the hand grasp with and without the neuroprosthesis. Yet the test is not meant to determine how functional the system is when used in a real environment. The development of a functional skills paradigm that addresses the global issue of usefulness to the subject is ongoing at our laboratory.

Table I

Task Name	Degree of Skill	Grasp	Functional Analog
Cubes	Simple	Palmar	small common objects
Cylinder	Moderate	Palmar	glass, phone hand set
Video tape	Difficult	Palmar	small book, actual video tape
Pegs	Simple	Lateral	pen, fork, paper
Disk	Moderate	Lateral	medium weighted small objects
Fork	Difficult	Lateral	eating, Writing, typing

Table II

			Avg. Completions Std. Deviation							Avg. Success Rate Std. Deviation		
Task	Skill	Grasp	#Pass /Pop.	With	#Pass /Pop.	W/O	#Pass /Pop.	TT-Cand	Normal	With	W/O	TT-Cand
Cube	0	P	4/4	11.7±4.6	3/4	9.3±9.5	4/5	12.6±10.6	46±2	90±7	74±26	70±21
Cyl	1	P	4/4	6.2±2.0	3/4	3.7±4.1	1/5	3.7± 7.4	47±5	80±15	67±18	89±0
Tape	2	P	1/4	1.0±1.7	1/4	0.4±0.6	0/5	0	38±2	91±0	35±0	--
Pegs	0	L	4/4	10.4±3.5	3/4	9.4±7.5	4/5	14.0± 7.6	30±3	94±8	76±17	78.5±5
Disk	1	L	4/4	7.0±5.4	0/4	0	0/5	0	46±4	95±4	--	--
Fork	2	L	2/4	1.8±1.9	0/4	0	0/5	0	41±4	100±0	--	--

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RULE BASED PROCEDURES FOR DEVELOPING HAND GRASP PARAMETERS IN FNS

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ABSTRACT

A set of rule based procedures has been developed for the determination of lateral and palmar FNS patterns used in our neuroprosthetic hand systems. These procedures use an electrode profiling output as the basis for choosing electrodes to be used and for determining the stimulus parameters. The end result of these procedures is a basic framework for each grasp. From this point, refinements to the grasp can be made as necessary. The method has been tested on a number of subjects in our clinical program and has proven to result in functionally useful grasps.

INTRODUCTION

Functional Neuromuscular Stimulation (FNS) of the upper extremity has been used as a means of providing quadriplegic subjects with both palmar and lateral grasps. The present neuroprosthesis uses a single proportional input command signal which is translated into the stimulus level to a number of electrodes implanted in various muscles. The purpose of this paper is to describe the method by which the parameters that translate command to stimulus level are developed and modified. This method will be presented in a rule based fashion.

PROCEDURE

The first step in the process of setting up a hand grasp is to obtain an electrode profile of all the electrodes available for the particular subject. The electrode profiling procedure, which involves rating the characteristics of each electrode is described in detail elsewhere (1). Once this has been obtained the electrodes are then grouped into the following functional divisions:

I. Thumb extensors (TE)
    1. Extensor pollicis longus (EPL)
    2. Extensor pollicis brevis (EPB)
II. Thumb flexors (FE)
    1. Adductor pollicis (AdP)
    2. Flexor pollicis brevis (FPB)
    3. Flexor pollicis longus (FPL)
III. Thumb abductors (TAB)
    1. Abductor pollicis brevis (AbPB)
    2. Abductor pollicis longus (AbPL)
IV. Finger extensors (FE)
    1. Extensor digitorum communis - specify digits (EDC,ilrs)
    2. Extensor indicis proprius (EIPi)
V. Finger flexors (FF)
    1. Flexor digitorum superficialis (FDS,ilrs)
    2. Flexor digitorum profundus (FDP,ilrs)

The best electrode in each category is determined by comparing the electrode profile ratings of the available electrodes in that group. Two basic grasps are set up: lateral (key grip) and palmar (three-jaw chuck). The procedures for these two grasps are described separately below. The specific command percentages given below may vary depending upon the needs of the subject.

Lateral Grasp

In the lateral grasp the fingers initially are extended and the thumb is fully extended. Within the next 20% of the command range the fingers are flexed linearly until they reach full flexion. The thumb position is changed linearly from full extension to contact with the index finger over the command range from 20% to 50%. Over the last half of the command range the thumb will apply force onto the index finger and this force will increase linearly as the command increases.

Developing the lateral grasp requires four functional components: thumb extension, thumb flexion, finger extension and finger flexion. The parameters for the lateral grasp is then determined for each functional group as described below.

Thumb Extension: First find the maximum stimulus level at which isolated thumb extension occurs (referred to as "TEx"). Then develop grasp parameters in following manner:

command %	stimulus value
0	TEx
20	TEx
60	TEO

where "TEO" refers to either a sub-threshold or zero stimulus level.

Finger Extension: First find the maximum stimulation where isolated finger extension occurs ("FEx") and set up grasp parameters as follows:

command %	stimulus
0	FEx
10	FEO

An electrode that primarily recruits the thumb extensors but also secondarily recruits the finger extensors can be used for both thumb extension and finger extension.

Finger Flexion: Find the maximum stimulus where isolated finger flexion occurs ("FFx"). The preferred finger flexor is the FDP. Spillover to the thumb flexor can also be utilized by determining the maximum stimulus prior to spillover to a third muscle ("TFx"). Parameters are determined as follows:

command %	stimulus
10	FFO
20	FFx
50	FFx
100	FFx or TFx

Thumb Flexion: Find maximum stimulus where isolated thumb flexion occurs (TFx) or use spillover from a finger flexor as described above. Set up parameters as follows:

command %	stimulus
50	TFO
100	TFx

Palmar Grasp

In the palmar grasp the finger position changes linearly from full extension to full flexion as the command changes from 0% to 60%. From 60% to 100% the force of the fingers on the thumb is increased linearly. The thumb position remains constantly in opposition throughout the command range. The palmar grasp uses three functional groups: thumb abduction, finger extension and finger flexion.

Thumb Abduction: Stimulus to the thumb abductor is maintained throughout the command range at the maximum stimulus where isolated thumb abduction occurs.

Finger Extension: Find maximum stimulation where isolated finger extension occurs ("FEx") and set up the parameters as follows:

command %	stimulus
0	FEx
55	FEO

Finger Flexors: Find maximum stimulation where isolated finger flexion occurs ("FFx"). The preferred finger flexor for the palmar grasp is the FDS. Set up the parameters as follows:

command %	stimulus
45	FFO
100	FFx

If only some fingers are recruited by the best FDS electrode, keep adding finger flexor electrodes until all four fingers are recruited. Each added electrode follows the same pattern as above.

In most cases it will be necessary to modify the grasp parameters developed by the procedure above. These modifications involve obtaining data not included in the electrode profiling procedure. Examples of reasons for these type of modifications are: high recruitment gain in one or more muscles, poor thumb positioning, lack of a selective electrode and lack of a necessary function due to denervation. Most of these require the use of cocontraction of two or more muscles to obtain the desired grasp output. Some alterations may require a reimplant of electrodes or surgical alterations such as thumb arthrodesis or tendon transfers.

CONCLUSION

The procedure outlined in this paper provides a framework for the development of FNS grasp parameters. It has been our experience that the resulting grasp will be functionally useful but will not be optimal. This procedure, however, is relatively simple and does not require complex instrumentation. The modifying and optimizing of the grasp requires further data to be obtained regarding the recruitment properties of the electrode/muscle combinations. We are presently developing methods where this information can be easily obtained. This would improve the quality of grasps developed by this procedure.

ACKNOWLEDGMENTS

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AN ENHANCED CONTROL ALGORITHM FOR AN UPPER EXTREMITY FUNCTIONAL NEUROMUSCULAR STIMULATION SYSTEM

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ABSTRACT

An enhanced control algorithm is implemented in the Case Western Reserve University upper extremity Functional Neuromuscular Stimulation system to provide a more natural control of hand grasp patterns by a quadriplegic patient. Enhancements from previous control algorithms include a lock detection scheme which is based upon the user's level of activity and the implementation of a mobile command/control range. These enhancements aid in providing the characteristics of a good controller, including a better coupling between the control input and hand actuation, minimizing unnatural movements and a reduction of the algorithm's complexity.

INTRODUCTION

The development of neural prosthetic hand systems implemented through Functional Neuromuscular Stimulation (FNS) for restoration of controlled prehension and release in C5 to C6 quadriplegics has been ongoing for the past several years in our center and has been employed on 27 subjects. These systems consist of chronically indwelling electrodes for neuromuscular and electrocutaneous sensory stimulation (1), transducer systems and either laboratory based (2) or portable (3) command processor and stimulator systems.

The FNS system, whether it is laboratory based or portable, consists of four functional blocks as given in Figure 1. Input command sources, controlled by the FNS user, can be comprised of a variety of transduction schemes. Implementation of transduction schemes to control neuroprosthetic hand systems have included contra-lateral shoulder movement, processed EMG and simple switches. The transduced command inputs are then processed by a supervisory control algorithm to provide state transition commands and stimulus parameter indexing. State transition commands are used within the supervisory control algorithm to direct the flow of control through the various states of the algorithm. The stimulus parameter index is used by the stimulus parameter modulator to coordinate and regulate channels of stimulus waveform parameters. The stimulus waveform parameters are then used by the stimulator output stages to provide a controlled prehension-release pattern and sensory information.

A typical system configuration consists of a two-axis joystick type transducer with one or both axis defined as a proportional command source and/or a logical command source. Another logical command source consists of a chest mounted switch for use in the non-dynamic control states. Two functional prehension and release grasp patterns are defined. One being a lateral prehension and release and the other being a palmar prehension and release.

The existing command/control algorithm, as described by Buckett et. al. (4), which is most often used in the existing implementation of the portable FNS system consists of seven states as opposed to the five states of the enhanced algorithm.

CONTROL ALGORITHM ENHANCEMENTS

The enhanced control algorithm, which has been implemented in our laboratory based FNS system, is represented by the state diagram given in Figure 2. The unit idle, mode selection and exit states and their entry commands remain the same as for the existing control algorithm. The time-out duration for the selection of the system's zero command reference and the need for a search state between the static and dynamic states is eliminated by the implementation of a mobile proportional command range. This is done by shifting the proportional command range accordingly when the FNS user moves the proportional command axis transducer past either extreme of the

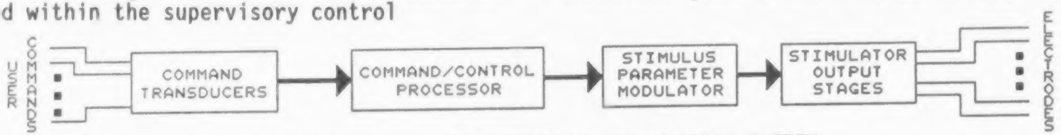

FIGURE 1: FUNCTIONAL NEUROMUSCULAR STIMULATION SYSTEM

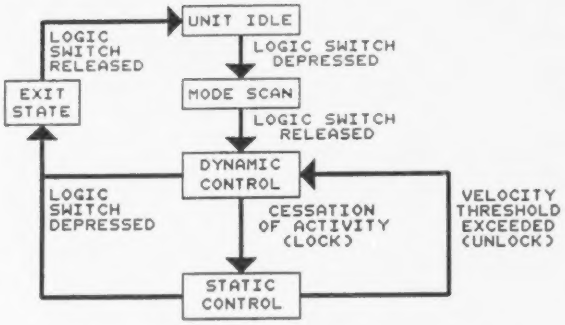

FIGURE 2: ENHANCED CONTROL ALGORITHM

predefined command range. The need for a conscious entry into the static control state is eliminated by sensing the magnitude of activity on the proportional command axis and automatically entering the static control state when the activity falls below a predetermined threshold. The detection of activity on the proportional command axis is based upon a filter of past and present activity. The most recent activity taken over a predetermined period of time is maximized and summed with an exponentially decaying value of past activity. Thus, the activity at any instant in time can be found by summing the most recent activity with the past activity.

DISCUSSION

The inclusion of a mobile proportional command range in the algorithm provides closer association between the user's proportional command and the grasp actuation by eliminating the deadbands inherent in the existing algorithm. The mobile proportional command range also allows for postural shifts by the FNS user without completely disrupting the command range. Without the mobile command range the user is required to exit the active use of the system and enter a new zero command reference point so that extremes of the command range can be reached at the new posture.

The substitution of the activity lock detection algorithm for the normalized velocity lock detection algorithm creates a more natural user interface which, as previously mention, eliminates the need for a conscious static control state entry command and eliminates the command lag between the user's desired command level and the actual level of stimulation that is necessary with the normalized velocity lock detection scheme. This lag is necessary in the present control algorithm due to the inability to isolate movements on the proportional and logical command axis.

CONCLUSIONS

The main objective in designing a command/control algorithm for use with a neuroprosthetic hand system is to enable the user to concentrate on the task rather than the operation of the FNS system. By implementing the command/control algorithm using modular techniques we have attempted to optimize the user's function of the FNS system. This optimization will be tested using techniques developed by Thrope, et. al. (5). Future efforts toward the optimization of the command/control algorithm will be directed at the remaining control states and providing more intimate command/control sites to the FNS user.

ACKNOWLEDGEMENTS

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ESTIMATING THE USER POPULATION OF A SIMPLE FNS SYSTEM

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INTRODUCTION

Functional neuromuscular stimulation (FNS) has been explored in many laboratories as a potential method of achieving standing (and sometimes walking) in carefully chosen paraplegic individuals [1]. There has not yet been complete consensus as to how many spinal cord injured individuals will benefit from this technology. Mobility needs are very important in this population [2].

The present study was designed to estimate the potential number of users of a simple FNS protocol for standing. Transient (5-15 min) periods of standing can be achieved by bilateral electrical stimulation of the quadriceps in individuals with thoracic injuries. Balance aids such as parallel bars or walkers are required. This protocol has been described elsewhere [1,5].

METHODS

Based on our previous work [1,5] and the work of investigators at the Rehabilitation Engineering Center in Ljubljana, Yugoslavia [3], proposed prescription criteria have been established for the successful use of this standing aid by paraplegic patients. These criteria are summarized in table 1.

Indications	Contraindications
Mid- to low thoracic level injury	High cervical cord injury
Upper motor neuron paralysis below level of lesion (muscular response to electrical stimulation)	Lower motor neuron injury of lower extremity with severe atrophy (electrical unresponsiveness)
Otherwise normal physical examination	Joint contractures, severe spasticity, decubitus ulcers, or medical complications (urinary tract infection)
Psychologically stable	Unrealistic expectations

TABLE 1: SUMMARY OF CRITERIA

A chart review was conducted of paraplegic individuals admitted to the Rehabilitation Institute of Chicago for the period 1982 through 1986. A total of 192 charts were reviewed. Data were recorded on a standard form, and entered into a computer database.

Estimates of the national spinal cord injured population were taken from a 1985 compilation of [4] and other sources [reviewed in 1].

RESULTS

A total of 192 cases were reviewed, all of which were classified as paraplegic. The mean age was 33.4. Approximately 80% of the cases were male, 20% female. For all spinal cord injured individuals (paraplegic and quadriplegic) national estimates for the mean age is 29.7 years, and 82% of the cases are male [4].

The criteria for protocol use were applied to this population in the order indicated in table 2. On each line of the table is the number of subjects remaining after the criterion of that line and all criteria above had been applied to the population, and in parentheses, the number of subjects eliminated by the criterion on the line. The percentage figure is percent of the original 192 subjects remaining. Associated medical problems included hypertension, osteoporosis, and cardiopulmonary problems.

CRITERION	No. Subjs		%
Paraplegic	192	(0)	100%
T4-T12 Lesion	120	(72)	63%
Absence of UE Injury	106	(14)	55%
KAFOs Prescribed	48	(58)	25%
Assoc. Med. Probs.	36	(12)	14%
No Substance Abuse	24	(12)	13%
Age 18-50	20	(4)	10%

TABLE 2: CRITERIA APPLIED TO CASES

The data presented in this paper suggest that approximately 10% (20 out of 192) of all paraplegic individuals in the RIC sample would be potential users of this simple FNS protocol for standing.

If this 10% estimate is applied to the national spinal cord injured population, then approximately 4.6% of all spinal cord injured individuals would be potential users of this protocol. The national SCI population was estimated to be 45.4% paraplegic (for 19831984) [4].

The actual number of patients who could use this protocol depends on the estimate of the population size, as indicated in table 3 [see 1].

PRESENT POP SIZE	POTENTIAL USERS
500,000	23,000
200,000	9,200
175,000	8,050
NEW CASES PER YEAR	POTENTIAL USERS
10,000	460
8,000	368

TABLE 3: ESTIMATES OF NUMBER OF USERS

DISCUSSION

The estimated number of users of this simple protocol was found to be relatively small. There are a number of factors which might make these numbers even smaller. These include such issues as contractures, primarily at the hip and ankle, spasticity, and psychological problems. These areas were not included in this preliminary report.

There are also a number of factors which might increase these estimates. For example, it may be possible to treat or control hypertension or other cardiopulmonary problems. Other clinicians may feel that the rather arbitrary age restriction we have imposed could be relaxed, or that relaxing the criteria for KAFOs prescription would be possible.

Restoration of mobility in spinal cord injury is an extremely difficult problem. This problem is compounded by individual variations in residual muscle function at particular levels of injury. Demonstrations of restoring mobility by FNS have been confined to a small number of centers with carefully selected and highly motivated patients. The data from this study could be interpreted to support the view that a number of different protocols for restoring mobility in spinal cord injury will be necessary if more than a small portion of the population is to be helped.

ACKNOWLEDGMENTS

This work was supported in part by NIH (SO7RR07027-20, SO7RR07027-21, HL39523, NS20860), NIDRR (G008435046, G008535129). RJJ was supported in part by a Mary E. Switzer Fellowship from NIDRR (133FH70022).

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ADVANCES TOWARD DEVELOPMENT OF MICROELECTRONIC AXONAL INTERFACE NEUROPROSTHESES

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ABSTRACT

The ongoing project described herein is to realize a microelectronic axonal interface to peripheral nerves for use as a means of correctly redirecting information across an injury site in regenerated peripheral nerves, an interface to prostheses and for basic science research. It is intended that the devices will function as a direct man-machine interface by establishing connection to individual axons when interposed between the two ends of a severed peripheral nerve. Axonal regeneration through via holes in silicon substrates has been demonstrated. These via holes have been fabricated using a plasma etch process which is compatible with the other microelectronics fabrication steps required to ultimately add active circuitry to the devices. Passivation using silicon nitride has demonstrated sufficient conformal coating capability to reach the depths of the via holes, thus protecting circuitry from harmful alkali ions in body fluids. Future research is also discussed below.

INTRODUCTION

The basic premise upon which this project is based is that if severed peripheral nerve axons are allowed to regenerate through via holes in a rigid substrate, microelectrodes fabricated at each via hole become spatially fixed with respect to each axon (figure 1). Electrical communication can be established between active circuitry on the substrate and the axons via the basic single axon/circuit subunit or "axel". Arrays of these elements could be used for re-routing signals in regenerated peripheral nerves (which tend to be scrambled due to relatively non-directed regeneration), interface to prostheses and research into neural signal encoding by enabling the study of groups of axons in parallel rather than singly. The project's background and work to date have been previously described [1], [2] and the focus of this paper is the reduction to practice of the microelectronic fabrication techniques required.

VIA HOLE FABRICATION WITH PLASMA ETCHING

While early via holes were fabricated via laser drilling [2], this process is not compatible with large-scale microelectronics fabrication on the same substrate. This motivated the development of a plasma etch process which is capable of producing via holes in silicon to depths in excess of 100 μm with aspect ratios better than 8:1. A plasma chemistry based mainly on fluourine free radicals was chosen, the reactants being SF_6 and C_2ClF_5. The six controlled process parameters were optimized for maximal selectivity for the silicon versus the photoresist, which is used to protect areas where etching is not desired. One of the non-intuitive findings of the optimization study was that the selectivity increased greatly as the RF power density in the plasma was increased. Test via hole arrays with opening sizes of 6, 8, 10 and 12 μm, covering the range shown by this group to be useful for capturing single mammalian axons, were fabricated in silicon substrates of various thicknesses (figure 2). The current process is compatible with the CMOS technology being used to design the active electronics to be co-fabricated on the substrate. These arrays were implanted in rats and the results of this study, not available at this time, will be published in a future article.

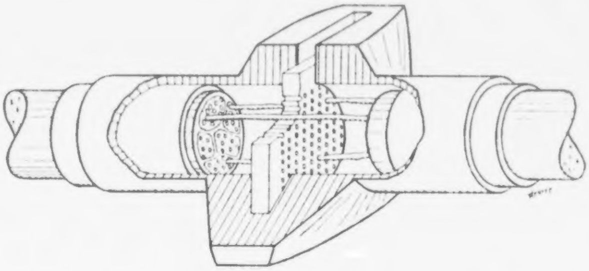

Figure 1, drawing of a microelectronic axonal interface held between severed nerve ends by a surgical coupler.

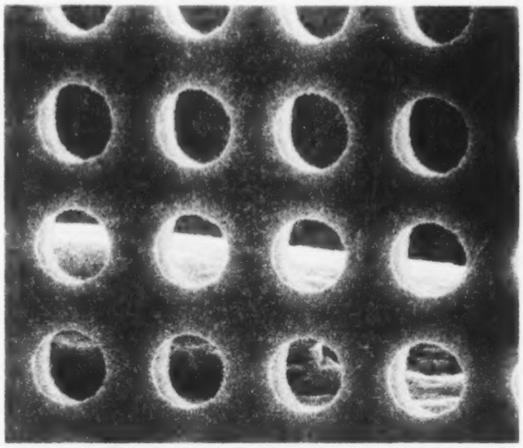

Figure 2, SEM view of 10μm via holes fabricated in a silicon substrate. (magnification = 750X)

SILICON NITRIDE PASSIVATION LAYER

Silicon nitride deposited via a plasma enhanced chemical vapor deposition (PECVD) technique was shown to be able to coat the sidewalls of the via holes to a test depth of 70μm (work done prior to fabrication of the deeper via holes). Due to the fact that the reactant gases do not react to form silicon nitride without electron bombardment, they are able to diffuse down the vias and react therein. As shown in figure 3, silicon nitride was deposited at the bottoms of the test pits to a depth of 0.5 μm versus 0.75 μm at the surface. Passive test devices coated with silicon nitride will be implanted and the nerves evaluated histologically in the near future.

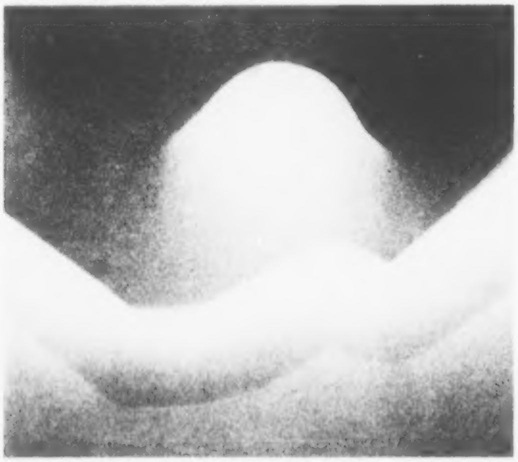

Figure 3, SEM view of silicon nitride film deposited on bottom of 70 μm deep test pit. (magnification = 22,500X)

METAL MICROELECTRODE FABRICATION

Metal microelectrodes located at each via hole are currently being fabricated using a gold lift-off process. The exposed microelectrode surfaces will be coated with iridium, likely deposited using an electrochemical technique developed at Stanford. Test arrays are currently being fabricated to examine the effects of various microelectrode geometries and surface areas upon their ultimate performance *in-vivo* . The microelectrodes will be evaluated using a low-frequency vector impedance analyser and various electrochemical techniques and the results used in the design of those in the active version of the device.

PHASE ONE ACTIVE MICROELECTRONICS

Design of circuitry for inclusion in the first active devices is currently underway. The design is being implemented in a 3 μm CMOS process and will be post-processed at Stanford to fabricate the remaining structures. Simulation and actual measurements will aid in determination of the thermal dissipation and its possible effects on the neural tissue in contact with the chip. The basic structure of the circuitry is an X-Y addressable analog switch matrix and is similar to that used in dynamic random access memory devices. It is designed to minimize coupling of internal switching signals to the external medium (and hence to the neural action potentials). Modelling using SPICE is being used to evaluate coupling for various geometries.

CONCLUSION

While we are still far from the clinical application of the microelectronic axonal interfaces, we are making steady progress towards this goal. It is hoped that the current set of experiments in progress will enable us to move closer still to our ultimate designs. Once even a crude version is realized, we can begin to gain insights into the nature of the parallel encoding of neural signals in the peripheral nervous system.

ACKNOWLEDGEMENTS

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SUPPORT

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"Pilot Study for Nerve Coupler", 1986
"Development of Coupler for Nerve Chip", 1986-7
"Towards Better Methods of Nerve Repair and Evaluation", 1987-9

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"SPECIAL INTEREST GROUP". 11

Computer Applications
Applications de l'ordinateur

SIMKA - A SIMPLE KEYBOARD ADAPTER

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ABSTRACT

In many cases, computer keyboard emulation requirements are limited to replacing only a few of the conventional keyboard's keys with switches. The switches then produce the same action as the original keys of the keyboard. This paper describes a simple device to provide this sort of adaptation.

INTRODUCTION

Regular computer keyboards are often difficult or impossible to use by disabled individuals. Solutions to this problem have ranged from simple mouth sticks to complete computer systems, dedicated to acting as special keyboards for target computers (1). The latter devices permit control of a wide variety of programs and offer flexibility by providing a wide range of input control options (2).

Many new software packages require the use of only a few of the keyboard's keys for control of the entire program. Consequently, a disabled use needs only a few switches for program operation. The problem is then reduced to providing such a person with specialized control switches and a device which converts switch closures into codes simulating keystrokes on a regular keyboard.

In Ontario, disabled students are integrated into the education system. It is important that they have the same access to the school's computer systems as the able-bodied students.

One of the computer systems used in Ontario schools is the ICON. The Ontario Ministry of Education has initiated the Schools, Computers and Learning Project in collaboration with Queen's University (Kingston, Ontario) and the Frontenac Board of Education. The puprose of this project is to study impact of computers on learning (ICON computers are used extensively). In order to accomodate the disabled students, we have developed the SIMKA interface.

METHOD

The block diagram of figure 1(b) shows one possible SIMKA (SIMple Keyboard Adapter) approach. The adapter is positioned between the keyboard and computer of the target computer system. Keystrokes from the keyboard pass unaltered to the computer. A five-switch interface is read by the SIMKA unit and the switch closures and openings are encoded into key scan codes to perform functions at the computer.

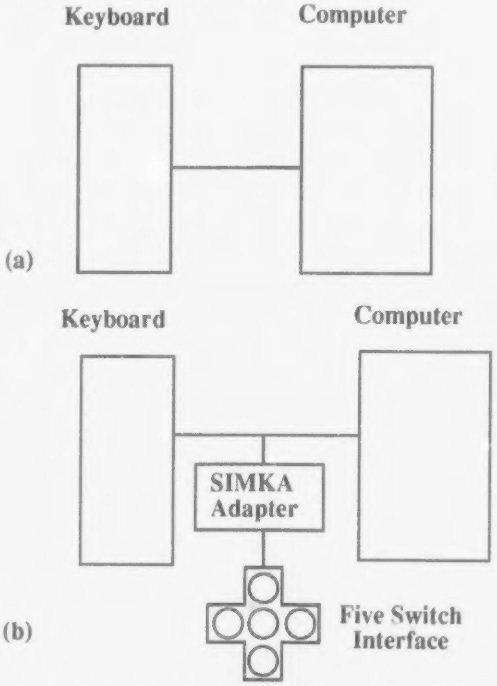

Figure 1. (a) Normal computer/keyboard arrangement, (b) computer arrangement with SIMKA added.

Figure 2 shows a block diagram of the implementation. A single chip microprocessor (68705P3) and an open collector driver (7406) form the only active components (total manufacturing cost $40). Power for the device is derived from the target computer.

The ICON computer provides a port for an auxilliary keyboard. When an auxilliary keyboard is attached, it can operate in tandem with the ICON's built-in keyboard. The SIMKA unit scans the switches. When a change in a switch state has been found, an appropriate code is sent to the auxilliary keyboard port. There are separate codes for switch closings (make codes) and switch openings (break codes). The actual codes, assigned to each switch are fixed in ROM (read-only memory), are determined by the needs of the application program.

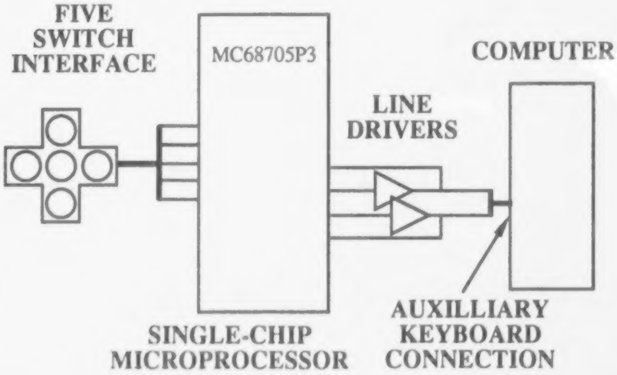

Figure 2. Block diagram of a SIMKA adapter for the ICON computer.

The first application of the SIMKA has been in a music appreciation program of the Project. All five switches of the adapter are used to control the operation of the program.

RESULTS

The SIMKA unit for the ICON computer has been developed and a prototype implemented. It has been tested with the ICON computer using several switch-to-keycode translations. A music training program with which the adapter will be used in future tests is presently under development.

The codes selected for the switch closures in the prototype SIMKA unit are program-dependent. They can be easily changed, for various applications, by altering the ROM of the interface. Considering the low cost of the SIMKA interface it is envisioned that several several SIMKA units will be available to suit several different situations.

DISCUSSION

Simple in concept and implementation, the SIMKA is a useful tool for disabled users. Although the present unit is programmed for one translation between key closure/ opening and output codes multiple translation tables will be tested with future prototypes.

Another possibility is a built-in switch training mode which would allow a user to customize the meanings of the keyswitchesat any time. The training mode would let the user close the interface switches and select appropriate keyswitches for translation by pressing the actual keys on the computer's keyboard. If the trainer program operated on the host computer, storing interactive keyboard translation tables on diskette (or hard disk) would be possible. (This would be possible only where there is bidirectional communication between the keyboard and the computer (Apple and IBM)). These developments would offer more flexibility at the cost of added complexity.

CONCLUSIONS

To provide new features, greater flexibility and speed of data entry, keyboard emulators have become more and more complex. There is, however, a need for a simple to operate, inexpensive keyswitch emulation device that performs a very basic function, i.e. facilitate replacing selected keyswitches with special external switches. The SIMKA adapter fulfills that need.

ACKNOWLEDGMENTS

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AN INEXPENSIVE, OFF-THE-SHELF APPROACH TO INCREASING COMPUTER KEYBOARD ENTRY RATE FOR SINGLE FINGER AND TYPING STICK TYPISTS

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INTRODUCTION

Because of cost, availability, and related problems with special computer input devices, the most frequent approaches to utilization of personal computers by hand impaired individuals involve using a typing stick (either hand or mouth held), or single finger entry on a standard keyboard. There is an obvious inefficiency in these approaches to keyboard entry when compared to two-handed touch typing. It was speculated that readily available, off-the-shelf hardware and software might provide a low-cost basis for reconfiguring the standard input system to make it more efficient for single finger and typing stick typists, and a project was implemented to explore the possibility.

Through a review of research and observation of typing stick users, five factors were identified which appeared to significantly affect the keyboard use efficiency of hand-impaired typists: a) the distance the finger or typing stick must travel, b) the speed at which the stick or finger can be moved, c) the time spent locating the keys to be pressed, d) interruptions evoked by the need to figure out how to expedite simultaneous key presses, e) and the number of key strokes required by some functions. These factors were all subsequently addressed in reconfiguring the standard keyboard system to accommodate hand impaired typists.

KEYBOARD DESIGN

To provide the basis for the enhanced standard keyboard entry system, an IBM PC type keyboard and keyboard utility software were purchased as a package for approximately $100. SuperKey[1] was most suitable for meeting the software needs of the project because of its low cost and capacity to support a variety of keyboard input functions. It is also a memory resident program, enabling use with applications software.

The distance the finger or typing stick must travel was reduced by utilizing a circular, or target-like arrangement as the primary guideline for the keyboard reorganization. The most frequently used letters in common written English usage are located in the middle of the standard four-row keyboard, as shown in Figure 1. The letter "E", which is most frequent, is at the center of the second row, and the remaining letters are arranged outward in order of decreasing frequency of use. Additionally, letters frequently used in combination are located near one another. The letter frequency and versatility studies of Solso and Juel, and Solso and King provided the data for determining combination usage (1) (2).

To facilitate development of an effective scanning pattern, the numbers 1-5 circle from right to left beginning near the center of the top key row, and the numbers 6-0 are ordered left to right. The keys are also color coded, with the "E" being red, the punctuation keys green, the numbers blue, and the miscellaneous keys yellow. The overall appearance is like a target, with the red "E" as the bull's eye, providing for a highly efficient scanning pattern and easy discrimination of key types.

```
~ [ ] 3 2 1 V U P 6 7 8 + |
   - 4 Q M I T S C K Z 9 :
    5 J G N R E H B Y X 0
     / " F O A D L W , .
```

Figure 1. Rearranged Key Layout

Two feasible ideas evolved with regard to the elimination of keystrokes. First, the use of macros, that is, the assignment of words, phrases or other multiple character strings to a defined and relatively limited keying sequence, was incorporated into the scheme. Five macro words were chosen by using a formula to determine which words utilized the largest number of keystrokes in common written English prose. The work of Kucera and Francis served as the basis for determining frequency of use (3).

A second means of eliminating keystrokes was to incorporate automatic spacing after some punctuation marks. Using software features, the keyboard system was configured to insert one space following the comma, and semicolon. Two spaces are inserted following the period, question mark and colon. This feature is designed so that it can easily be disabled, if desired.

The final enhancement to the keyboard input system was to utilize the software's "single finger" mode. This enables entering keyboard commands, which normally would require simultaneous, multiple key presses (e.g., Shift and a letter key to type upper case), to be entered as sequential commands.

EVALUATION

The described keyboard entry system was evaluated in a research study that followed a formal experimental paradigm. Single finger typists were tested using the system in conjunction with a word processing program. The findings from that study indicated that single finger typists using the reconfigured keyboard system attained entry rates more than 50% higher than a group using the conventional QWERTY layout without other enhancement. This limited study suggests that the standard computer keyboard input system can be effectively enhanced to improve the proficiency of hand-impaired typists. However, analysis of the data from the study, which included information obtained during debriefing interviews, also revealed that the word macros were not used. The keystroke sequences were reportedly difficult to remember or associate with the words.

MODIFICATION

Following this study, a new macro system was obtained that provides a more natural approach to their configuration and use. The approach is more accurately described as a shorthand system because it enables users to form macros with abbreviations of words instead of using alternate or control key sequences. For example, re can be used to represent "rehabilitation," so that entering the two letters and pressing the space bar will cause the entire word to be spelled out in the text. In essence, the system supports a natural cognitive flow that facilitates learning and using macros.

A second addition to the enhanced keyboard system that stemmed from the information gained from the study is a cursor control program. It was observed that time was often lost when subjects were moving the cursor around the text they were working with because the cursor often overshot the desired position when they held the cursor movement keys down to utilize their repeat function. This "cursor skid" problem has been eliminated by a commercial program designed specifically for this purpose.

CONCLUSION

Although the keyboard entry system with the additional enhancements has not been evaluated in a formal study, several typing stick users have reported it to be superior to the original version. In general, they report that the total system has substantially increased their productivity and lessened fatigue in a spectrum of computer activities. In general, the experience gained from this project indicates that there are numerous relatively low-cost, off-the-shelf productivity enhancements that hold substantial potential benefit for persons with disabilities.

FOOTNOTES

1. SuperKey is a product of Borland International, Inc., 4585 Scotts Valley Drive, Scotts Valley, CA 95066

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APPLICATION OF VOICE RECOGNITION DEVICES FOR COMPUTER ACCESS AND PROGRAMING

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INTRODUCTION

Computer voice recognition applications provide powerful input tools for the disabled who have repeatable and functional speech control[1,2]. Investigators at the University of Tennessee at Chattanooga (UTC) have developed an application of computer voice recognition which enables the design and execution of BASIC programming language programs by users without keyboarding skills, but with voice capabilities[3]. This report uses that application system to introduce a range of commercially available voice recognition systems, discuss the limitations and problems involved in the installation and use of these systems, and illustrate the procedures for using a typical recognition system.

The voice BASIC programing application itself is a product of UTC's Rehabilitation Interface Engineering (RIE) Group at the Center of Excellence for Computer Applications (CECA). The CECA RIE group has chosen to focus its applications efforts on microcomputers, and personal computers specifically, as being most applicable in the rehabilitation area. The voice programming system was developed as an educational and vocational rehabilitation tool for specific individuals, but is entirely applicable to any voiced individual who lacks keyboarding skills, for whatever reason.

METHODS

The investigators chose to perform advanced development of a voice system i.e., apply technologies which are in, or nearly in, the commercialization stages for development, rather than attempt to perform basic research and development in the speech recognition area. Efforts proceeded in the following manner:

1. A literature search was performed for voice recognition product reviews and comparisons[4].
2. Commercially available voice recognition systems were cataloged[4].
3. A range of products, representative of the field, were obtained by grant or purchase.
4. Each system was installed and tested for reliability, speed, accuracy and ease of use.
5. One of the systems was chosen as typical for the application.
6. The required vocabulary for programing in the BASIC Language was listed and broken into categories such as commands, alphanumeric characters, and remarks.
7. A detailed menu structure of the vocabulary was developed.
8. The voice system was trained for recognition of the vocabulary.
9. The system was tested by students and then tried by a high-level quadraplegic who supplied part of the original motivation for the development.

RESULTS

Typical Voice Recognition Systems

The systems which have been evaluated are:

	System	Price
1.	Vocalink SRB-LC Interstate Voice Products	$395
2.	The Little Dictator Computer Peripherals Inc.	$495
3.	TI-Speech System Texas Instruments	$1300
4.	Vocalink Series 4000 Interstate Voice Products	$6000

The first three systems are discrete word recognition systems and the last is a connected word or phrase recognition system. The SRB-LC shares the CPU of the host microcomputer, while the others have on-board processors to speed up and ease the recognition process. The TI-Speech system includes a voice synthesizer and telephone options, so the cost comparisons are not for equal features.

Limitations and problems

Each of the systems specify recognition

accuracies of over 90%. After training the system's vocabulary, and some initial user experience in consistent repetition, recognition accuracies approaching 99% can be achieved.

The speed of performance by the systems is directly related to the size of the vocabulary used, and the menu structure, i.e., the number of words in the active vocabulary at any one time. For the BASIC programing application, the delays for recognition were in the order of one second, and were barely noticeable. The major delays were in the time taken to move from menu to menu to cover the vocabulary necessary.

A problem not normally mentioned in the application of voice recognition is the possibility of mistake generation due to improper recognition. If voice commands are used, improper recognition and the resultant system operation can be disastrous, e.g., the formatting of a disk by mistake, which destroys all the data on that disk. Proper choice of unique words for such "dangerous" commands can help avoid these problems.

All systems evaluated suffer from a difficulty in installation and application due to lengthy and hard-to-understand documentation. Friendly tutorials and interfacing software are necessary to make these tools useable by the very people who need them.

DISCUSSION

Application of a typical system

1. Building a menu structure. Each system provides software to build a vocabulary menu structure, by specifying the words to be recognized, the words to be in the active vocabulary at any one time (submenu), the commands to switch active submenus, and the alphnumeric strings to be generated and delivered to the system for each recognized vocabulary word.
2. Training the system. Each system contains software for building templates or patterns of the user's voice while speaking the vocabulary words to be recognized (training). Normally, about two to four repetitions of each word is sufficient for reliable training of the system. These templates are then stored as a file for use by that particular user.
3. Loading the system. Software can load the stored templates and activate the particular recognition system, to put the user in voice command of the system.

CONCLUSIONS

1. While current voice recognition is not perfect, there are systems available, at reasonable cost, with high accuracy, that are useable for many applications.
2. The main problem with current systems is the lack of a friendly and easy-to-use tutorial and interface. This deters the very person who needs the system from learning how to use it.
3. It is now possible for people with no keyboarding skills to design, write and execute BASIC programs via voice control. This result can easily be extended to other programing languages and to other software applications such as Lotus and dBase III.

ACKNOWLEDGMENTS

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FREE WHEEL
The cordless new headpointing device

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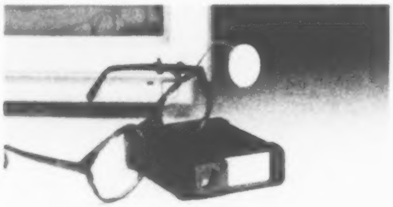
INTRODUCTION

Free Wheel is a new cordless headpointing device for the severely disabled. The computer has made life much easier for many people, and with Free Wheel all this is now available for the severely disabled user. Free Wheel allows the severely disabled person to access the microcomputer (including the laptop) with standard software almost as the able bodied person. Free Wheel allows the user to make cursor movements and keyboard entries simply by moving the head, arm or leg.

EXISTING SYSTEMS

The following headpointing devices are or have been on the market. 1)The headmaster from Personics, which is based on ultrasonic technology: the user must wear three transducers and a switch on the head and the headset must be connected by a cord to an electronics box. 2)The long range lightpen developed by the Trace institute: two CRT monitors are needed in this system and a cord is needed between the user and the electronics. 3)The Nod system from Stride: This system works on only special computers and measures only the translation of the users head movement. 4)The SpaSynCom from Polhemus Navigation Systems Inc.: This system is based on electromagnetic technology.



DESCRIPTION OF FREE WHEEL

Free Wheel is shown in the picture. Free Wheel consists of a reflector,a camera, and a software driver. The reflector must be worn on the user. It can be placed on any part of the users body over which the user has some control. No cord is needed between the user and the computer or the camera. The user is totally free to move wherever he or she wants to go. The camera can be placed at anywhere as long as it aimes in the general direction of the user. The camera must be plugged into the computer. It connects into a standard serial port or the mouse port. It draws all power from the computer.

Free Wheel transmits very short pulses of infrared light towards the user, this light is reflected by the user's reflector, and the camera will take pictures of the reflector's position and rotation changes. The relative changes in position and rotation are translated into cursor movement right-left and/or up-down. The cursor movement signals are sent to the computer, where the software driver takes control and feeds them into the software, which the user has selected to use. For cursor movement, it will seem to the computer software as if the signals came from a mouse and for keyboard selection, it will seem like it was inputted from the keyboard keys. Free Wheel compensates for any ambient light and reflection from other shinny objects Free Wheel works well side by side with other Free Wheels as well as in sunshine.

APPLICATIONS/INSTALLATIONS

A one time installation is necessary for Free Wheel. Just load the software driver into the computer memory and connect the camera to the computer.
The user can use Free Wheel with any software available for a microcomputer. The software driver is simply transparent and overlays itself onto all programs. The driver consists of two parts: a) A popup keyboard with wordprediction features and b) A cursor control driver like a mouse cursor driver.

The user can cause a popup keyboard to appear on the computer screen. The size and placement of this keyboard can be adjusted by the user by simple commands. Free Wheel measures the translation as well as the rotation of the users head. It enables the user to simply look at whatever character or word he or she wants to input into the selected software program in use. It has the intuitive "look at what you want" feel to it: wherever the user looks the cursor will appear. Free Wheel is an absolute headpointing device. The user can move his or her head sideways, left-right and/or up-down, or simply rotate the head and the cursor will move accordingly on the computer screen. If the user does not want keyboard selections he or she can make the keyboard disappear by a simple command. He or [illegible] can also easily make it reappear, when use is wanted.

The driver provides word prediction features. A keyboard with all the standard characters (keys) and the most common words will appear when the user starts up Free Wheel. The user can select either a character or a word he or she wants by simply moving the cursor to the wanted block and start the selection process. Free Wheel comes with two choices of buttons A) A time and position button: The user must keep the cursor on the wanted block for a predetermined time, and a selection will then happen. B) Any kind of switch which fits the users ability: Free Wheel comes with a standard 3.5mm switch connector. The switch can be a sipp or puff switch on a goosseneck or a push switch placed in the vicinity of the user.

It is possible to simply drive up to the computer with Free Wheel attached to it and Free Wheel will turn on automaticlly for the user. When the user leaves, Free Wheel will go into a standby mode, drawing very low power and waiting for the user to come back. This enables freedom and total independence for even the severely disabled user for the use of a computer.

Free Wheel is calibrated at the factory, with a setting which enables most people to use Free Wheel very comfortably. It is easy for the user to adjust this calibration, if he or she should so desire. Adjustments include the speed of selection, time and position selection time, movement needed for moving the cursor from the left side of the screen to the right side of the screen, and movement needed for moving the cursor from the bottom of the screen to the top of the screen.

The reflector can be attached to a pair of glasses, a cap, a headband, or what ever else the user can imagine to put it on.

USERS

Free Wheel was conceived for the severely disabled person, who can move only his or her head. It can be used by people with cerabal palsy, by stroke victims, by those with spinal core injuries, and many more. It can, of course, also be used by people who have more movement ability.

Free Wheel simply allows these people to open the door to the computer world, and thereby to the mainstream world, because they can use any existing software program. It allows them to communicate when used with a speechsynthesizer and/or printer, communicate over the phonelines via a modem, and control the environment through environment controllers. It could simply open the door for employment as productive people in the society as programmers, writers, accountants, etc.

CONSULTANTS AND USER FEEDBACK

The company is in constant contact with professionals in the disabled field. Free Wheel will be throughly tested at betatest sites, before the product will be finally released into the general market. This will enable the company to collect sufficient user feedback to get the product into the stage, which serves the disabled user the best. Pointer Systems enjoys a very close relationship with the Trace Institute and its director Dr.Greeg Vanderheiden.

THE COMPANY

Free Wheel is scheduled to be on the market in spring of 1988. It will be made for the IBM and IBM compatible computers. A Free Wheel for the Apple family computers will follow shortly thereafter.Free Wheel can give the severely disabled user access to the computer and all existing software programs, with the only added expense being Free Wheel. All the other computer system components can be shared with able bodied family members or friends.Free Wheel can also be used as a retraining tool for people who have had a stroke or other accident. It can be used easily with games in order to make recovery more fun and faster. It can futher be used in biomechanics for various evaluations.

ACKNOWLEDGEMENTS

The authors wish to give thanks to William Murray and Kate Seemann, whose encouragement and support made this achievement possible.

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ALTERNATE ACCESS TO APPLE AND IBM FORMATS IN ONE COMPUTER SYSTEM

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ABSTRACT

When recommending computer systems for individuals with disabilities, oftentimes clinicians must make a decision between two types: Apple DOS and IBM MS/PC DOS (1). In addition to the computer system, alternate access in the form of keyboard emulation is required for persons with physical disabilities. This paper describes a complete system that allows alternate input acccess to both Apple and PC DOS software.

INTRODUCTION

Thirty-seven million of the 242 million persons living in the United States are classified as having disabilities. Gaining the freedom to be gainfully employed, participate in recreational activities, and live to the maximum of their capabilities is the greatest challenge faced by individuals with disabilities. Technology serves as an equalizer to provide many of the same educational, vocational, and leisure opportunities as those available to nondisabled persons (2).

BACKGROUND

Clinicians, educators, and engineers are often involved in recommending computer systems for institutions, agencies, and specific persons. In the early 1980s the decision was easy: the Apple II computer system had been available in its form for several years, a rare phenomenon in computerdom, and third party companies had developed much in terms of software and peripheral devices. Because of its open architecture and the availability of one of the first keyboard emulating devices, the Adaptive Firmware Card (AFC) from Adaptive Peripherals, the Apple II system became the computer of choice for persons with disabilities. The combination of the AFC, allowing a wide variety and large number of input methods (3), and Apple computer remains a good choice as the Apple still enjoys popularity in the school systems.

The selection process has been made more difficult because of two factors: the advent of the MS/PC DOS based standard of business computers and the requirements of the funding source. With funding monies scarce, the future must be considered when recommending a computer system type: the system chosen must be expandable, updatable, and usable for both education and work.

SOLUTION

With the introduction of Trackstar, both computer systems are possible without the expense of purchasing both. Trackstar, available through Diamond Computer Systems, Inc., is a board that fits an expansion slot of the IBM PC and XT and true compatibles and features the 65C02 microprocessor used in the Apple IIe and IIc computers. Trackstar offers a full 80 column mode, 128K of RAM, both RGB and composite video output, and double high resolution graphics; and Trackstar supports Apple DOS 3.3, Pro-Dos, and Apple Pascal. Although Trackstar has the ability to utilize the internal disk drives of the host machine (the PC DOS machine), the addition of an external Apple compatible disk drive increases the patibility to 97%.
Expansion slots are not available, but Trackstar allows access to those devices that interface to either the 9-pin joystick port or the 16-pin DIP socket and emulates the standard Apple parallel and serial interface cards utilizing those ports in the host computer for execution.

The MOD Keyboard, marketed by TASH of Canada, was selected because of its design. The MOD Keyboard consists of a cartridge which, when inserted into a Commodore Vic 20, forms the basis of a keyboard emulating system that permits alternate access. The cartridge is equipped with 32K of EPROM to store the MOD Keyboard program and with 16K of lithium battery backed CMOS RAM for storage of user created customized display screens (4). Available is a variety of alternate access: single, dual, and multiple switch scanning; one and two switch Morse code; and expanded and reduced types keyboards (5). With the appropriate cables the MOD Keyboard can be interfaced to a variety of computers, a distinct advantage the MOD Keyboard has over the other keyboard emulating devices in the same price range. The cable interfacing the MOD Keyboard to an PC DOS computer system connects to the keyboard port.

The Tandy line of computers was chosen as the PC DOS computer system for several reasons: reliable performance, MS DOS compatibility, upgradability, expandability, service, and support. Trackstar may be plugged into a variety of Tandy computers including the 1000SX, 1000TX, and 2000. To connect the MOD Keyboard to a Tandy computer, a universal keyboard interface must be used.

CONCLUSION

In the United States the computer is still viewed as an educational tool rather than as a prosthesis for independence. With physical accessibility a reality, financial accessibility will follow with the recognition by funding sources that computers have the potential to reduce costs (6). A good start is a complete computer system that allows alternate input acccess to both Apple and PC DOS software.

ACKNOWLEDGEMENTS

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SINGLE-SWITCH EXPERT SYSTEM INTERFACE FOR ENVIRONMENTAL CONTROL AND COMPUTER ACCESS MODULES

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INTRODUCTION

Researchers at the University of Tennessee (UTC) have developed a single-switch actuated expert system for environmental control and communication. This expert system provides control facilities for three modules: guidance and control of environmental and mobility devices, friendly interface to the Disk Operating System, and a word-processor and calculator. This paper describes the prototype project results.

METHODS

The prototype version of this expert system was developed using the TI PC Easy expert system shell [1]. The PC Easy was chosen because of its natural language interface and graphic facilities which were used extensively to speed up the development of the prototype. The prototype was developed in order to focus the initial developmental efforts on building the "links" between the three modules. With these links defined, an enhanced expert system can then be coded in a more efficient manner.

The implementation under development is being coded in C. The major considerations involved in selecting C as the principal computer language included: the capabilities of C to interface with the microcomputer hardware components, the speed at which it executes and the fact that the modules to be integrated had already been coded in the language. Interface with the hardware was especially important because it was decided to utilize standard single-switches to provide access and interface to the system. Finally, it was very convenient, using C, to load and execute files from the main module. Control had to be transferred back to the main module after any of the auxiliary modules had been executed.

The IBM PC microcomputer was selected because of its wide usage and the large selection of peripheral devices, language compilers and expert system shells available.

User-friendliness was the most important consideration identified during discussions with care providers and clinicians. Most of the available keyboard emulators provide menus of characters at the bottom of the screen. These menus are difficult to redesign and adapt to specific user needs.

An expert system also can provide friendly access by presenting the user with a series of graphic screens. The natural language facilities available in most expert system shells, combined with graphic capabilities, help improve comprehension and speed of selection. Such facilities, once selected, can be implemented in C [2].

Another important need identified was the ability to control the physical environment. By including an environmental control unit, individuals could operate thermostats, stereos, lights and other appliances. The expert system provides access to the Environmental Control module, ECM-1, and assists in selecting and loading parameters to activate and deactivate appliances [3].

RESULTS

The prototype expert system accesses and manages three operational modules.

The Environmental Control Module (ECM-1)

This module allows disabled individuals to control their physical environment. This control is provided through electronic appliances or devices plugged into the household or building electrical sockets. The ECM-1 unit translates requests from the computer into signals that are transmitted through the AC lines in the building [2,4]. The signals are decoded to activate or deactivate the appliances as instructed by the user. A Heathkit Interface Model GD-1530 was used to build an interface between the computer and the BSR X-10 equipment [2,5].

The DOS Module (DOS-1)

This module provides an interface to the Disk Operating System utilized by the IBM PC's. DOS commands can be assembled and executed from this module. In addition, help and explanation capabilities are provided to facilitate the operation of the computer [6].

The Wordprocessing/Calculator Module (SET-1)

The module is a communication environment that allows the user to construct text by selecting letters, words and phrases from programmable menus. The text can be directed to a printer or to a voice synthesizer. The calculator capabilities provide means of performing simple arithmetic operations [7].

The scanning rates can be adjusted from each operational module. Another scanning method uses the PC AID card. The card provides access to the computer using a single/dual switch method instead of a keyboard [8].

DISCUSSION

The prototype expert system proved to be effective as a friendly front-end. The natural language facilities are helpful in directing consultations with the user and in providing help and explanation capabilities. Expert system shells also provide capabilities to design and construct screens and menus to support the system. Finally, the knowledge built into the system's rules directs the user to the appropriate module. The knowledge is transparent to the user and reduces the mental and physical burden on the individual. Changes in the knowledge base can be made easily without extensive recoding.

The expert system provides the environmental control unit with default values for the various parameters to be considered. Since the expert system provides initial settings, the individual need only be concerned with changing values as the needs change.

The implementation in C is being undertaken to enhance the scanning capabilities of the system. In order to implement scanning using the PC Easy version of the expert system, it was necessary to use the PC AID card or some other standard keyboard emulator. Use of the PC AID card, with the SET-1 module, presented new challenges: first, the software that complements the card is "memory-resident" [8] and interferes with PC Easy; and secondly, the module had to be scanned twice, the first scan will select a command from SET-1. A second scan is then required to select a <RETURN>.

The double scanning, required using the PC AID card, significantly deteriorated the performance of the system. Double scanning could be overcome by installing two interface switches. One switch could be dedicated to the PC AID card; the second switch would operate in the SET-1 scanning mode and would not require intervention from the card.

Planned enhancements to the system include: automatic calculation and selection of scanning rates, the inclusion of a microcomputer diagnostic and monitor system (currently under development) [6], enhancement of the screen editing facilities, and a wider selection of scanning methods.

CONCLUSIONS

The prototype expert system is an effective interface to switch-actuated computer access modules for environmental control, word processing and DOS interface. The expert system interface allows the user to select, access and operate each operational mode. Modularity was a major factor in the system design. The system can be expanded and interfaced with switch-actuated controls for mobility and standard software packages.

The difficulties associated with "ram-residency" and double scanning require further efforts. Recoding of the expert system in C language should overcome these problems.

ACKNOWLEDGMENTS

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ONE SCREEN MULTIPLEXED KEYBOARD FOR TRANSPARENT ACCESS TO STANDARD IBM PC SOFTWARE

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INTRODUCTION

Most of the software available for IBM PC and compatible computers requires information to be entered from a keyboard. People who cannot use the standard keyboard because of physical disabilities are barred from using this software unless modifications are made to the computer system to provide an alternate keyboard. The ability to access this software is very important for people with physical disabilities due to the increasing use of computer systems in educational, vocational, and daily living activities.

One type of alternate keyboard uses the headpointing capabilities of people with physical disabilities. Current headpointing systems for transparent computer access require a separate display for the alternate keyboard. This creates a two-display computer access system, one for the alternate keyboard and the other for use by the application program. Examples of current systems that use a separate display include the Express III (1), Long Range Optical Pointer (LROP) (2) and the Trine System (3). The limitation of a dual-screen system is the additional cost of second display and the lack of portability when a portable computer system is preferred.

There are several reasons the dual screen approach has dominated transparent computer access techniques. First, most application programs that run on the IBM PC take full control of the standard display resources. It would be impossible for an alternate keyboard display to reside on the same screen while the application program is running since it would constantly be writing over the alternate keyboard. Even if the alternate keyboard were constantly redrawing itself it would block potentially important information displayed by the application program. Another problem is the number of screen modes available on the IBM PC on which the alternate keyboard would need to be displayed. Many of these modes only provide character-level graphics capability, limiting the resolution of showing where the user is pointing. Current transducers that detect the user's pointing cause additional problems. Many of the transducers are dependent on their own display technology, which is incompatible with standard video and LCD displays found on computer systems.

PURPOSE

This project explored the ability of multiplexing the standard CGA display of the IBM PC for use as an alternate keyboard while also being used to display information from the application program. This requires suspending the operation of the application program, saving the current mode and contents of the screen, and drawing the keyboard image on the screen. After keys have been selected from the keyboard and before they are sent to the application program the keyboard must be removed and the application screen information restored. Figure 1 shows a person using a headstick to select keys from a computer keyboard. The individual looks at the keyboard to type, and then to the screen to see the results. The Trace One-Screen program functions similarly (Figure 2), with the user raising his head slightly to remove the keyboard image from the screen and redisplay the application program.

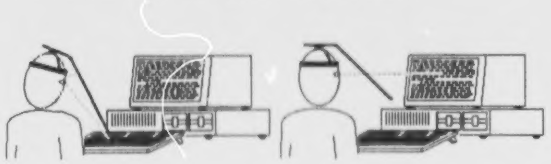

Figure 1

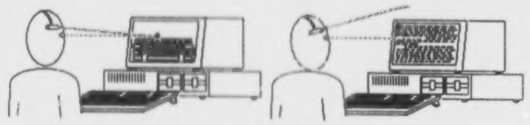

Figure 2

Keyboard Design

One of the most important design considerations is the ability of the user to functionally use an application program being multiplexed on the same screen with a keyboard. The user in this computer environment is interacting with the application program in a series of tasks of entering information into the computer and then watching to see the effect. When the user wants to begin to type into the application program they first point toward the screen; the application program is suspended, and the keyboard image appears on the screen. The user selects keys from the alternate keyboard and then points off the screen to allow the keys selected to be sent to the application program. When the user moves off the keyboard, the application program is restored to operation and the keys are given to the application program, allowing the user to see their effect. In this situation the user cannot instantaneously see the effects of the selected keys on the application program. While this may not be a big problem when typing in words into a word processor, it becomes a more difficult problem when the user is transversing a menu or scrolling through a document with arrow keys.

Screen Multiplexing

Whenever the user points toward the screen the alternate keyboard appears. Once the keyboard appears the user can return to the application program by pointing off the screen through the break in the top and bottom borders (see Fig. 3). The user can peek at the application screen by moving the pointer through the break in either the left or right borders. The rest of the border constrains the user from moving off screen. This assists in the selection of keys near the edge of the screen, since people tend to overshoot targets (4) when they are moving a pointer to the target area (in this case a key). Without the border the overshoot would typically cause the user to point off screen, removing the keyboard and disorienting the user about where they are pointing. The border therefore constrains the user from inadvertently moving off screen and allows them to continuously monitor their pointing movements.

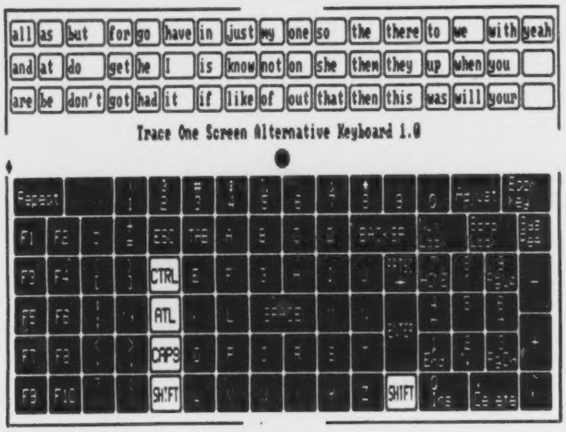
all as but for go have in just my one so the there to we with yeah
and at do get he I is know not on she them they up when you
are be don't got had it if like of out that then this was will your
Trace One Screen Alternative Keyboard 1.0
Repeat
Adjust
F1
CTRL
ATL
CAPS
SHIFT
SHIFT
ENTER

Figure 3

Three features make the software particularly interactive and usable. First, the screen switching mechanism is almost instantaneous, allowing quick change between the application and the keyboard. Second is the ability to look at the application program without sending the keys contained in the keyboard buffer. This allows the user to peek at the application screen to see where they are with in the application program without actually allowing it to run. Finally, a repeat key allows the user to have a key repeated at a user-specified rate as they watch the effects on the application screen. The repeating key is released when the user points back toward the keyboard. This is useful when the user wishes to scroll through a document or delete a string of characters.

Key Selection

Keys are selected on the alternate keyboard by holding the pointer on a key for a user-adjustable period of time. If the user continues to hold the pointer on a key it will be repeated automatically. The repeat time is also adjustable by the user; it can effectively be defeated by setting the repeat time to a large value. Each time the user selects a key the spot used for indicating where the user is pointing is temporarily removed and a tone is sounded. This provides the user with both auditory and visual feedback of key selection. The audio tone can be turned off if it is distracting to the users or others in the working environment. As keys are typed they appear on a display line just above the keyboard so the user can easily see the keys they have typed into the buffer. If a mistake is make the user can correct it by deleting the key from the key buffer before it is sent to the application program.

The IBM PC has four modifying keys on the standard keyboard (Control, Alt, Left and Right Shift keys) that are held down simultaneously with other keys to change their function or character. Since the pointer only allows one key at a time to be selected on the alternate keyboard these keys must be effectively held until the next key is selected before they are released. The modifying keys can be held only for the next key stroke or can be locked on for a series of keystrokes. This is called tri-stating the switches, since the switches can take on one of three states; Off, Effect next key only or Effect all subsequent keys until turned off. The states are manipulated by sequentially selecting the modifying key. The state of the modifying key is displayed above the output key display.

To increase the effective typing rate the 50 most commonly used words are displayed and can be directly selected by the user. The words appear on the top third of the keyboard image.

Adjusting Keyboard

The user can adjust key selection and output parameters in an adjustment menu. The ADJUSTER key on the keyboard switches the display to a adjuster menu. From the menu the user can change values by pointing at keys to either increase or decrease values or to turn Boolean variables on or off. Currently programmable variables are:

Key Selection time (.18 - 2.00 seconds)
Key Repeat time (.37 - 4.00 seconds)
Key Selection Tone On/Off
Movement Amplification (1-9)
Output Typing Rate (range:1-99 keys/second)
Output Repeat Rate (range:1-99 keys/minute)

CONCLUSION

The program developed demonstrates the ability to produce a one screen alternate keyboard for IBM PC DOS desktop computers and their compatibles (including portable computers with LCD displays). This development will help reduce hardware costs of computer access systems and provide a link to portable MS-DOS computers for portable writing and computer access systems. The program is currently compatible with Microsoft Mice and compatibles and with the Long Range Optical Pointer. Other pointers which do not already emulate the Microsoft Mouse will be adapted for use with the software as they become commercially available.

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INTERFACING THE DISABLED TO COMPUTER SOFTWARE THROUGH VIRTUAL INTERFACES

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INTRODUCTION

One of the challenges rehabilitation engineers face is interfacing disabled persons who are handicapped due to severe neuromotor dysfunction to computers so they can communicate and become productive in a work setting. Usually one must compromise between the employer's needs and the current technology. MacDonald 1) defines the problem as "there are very few software programs which are usable by, and appropriate for, people with sensory or physical disabilities. Most of the software that has been developed has been for one specific person for one specific need." There are systems for the handicapped which produce text but these do not produce files readable by business systems. For common management tools such as spread sheets and data base systems there are no current solutions. To overcome these limitations a method needs to be used which will interface software methods currently used in computerized augmentative communications to commercial business software. This method would involved a virtual software interface. For use with IBM PC systems we have developed a virtual interface module (VIM) which works with software operating under MS DOS.

METHODOLOGY

Our VIM is a gateway between augmentative communications software which interfaces the disabled with the computer and commercial software commonly found in the business setting (Fig.1). It is a memory resident program that can be invoked at any time. When invoked a special window is opened on the computer monitor. Through this window the user has control over commercial software using computerized augmentative communication methods. It has a flexibility that allows users to choose the input device with which they feel most comfortable. It can be operated from switches, the cursor keys on the keyboard, or with a speech recognition system. It can operate in scanning modes using a single switch control or use four switches for more efficiency. Any input device that can be connected to provide input through an I/O port can be incorporated into the VIM.

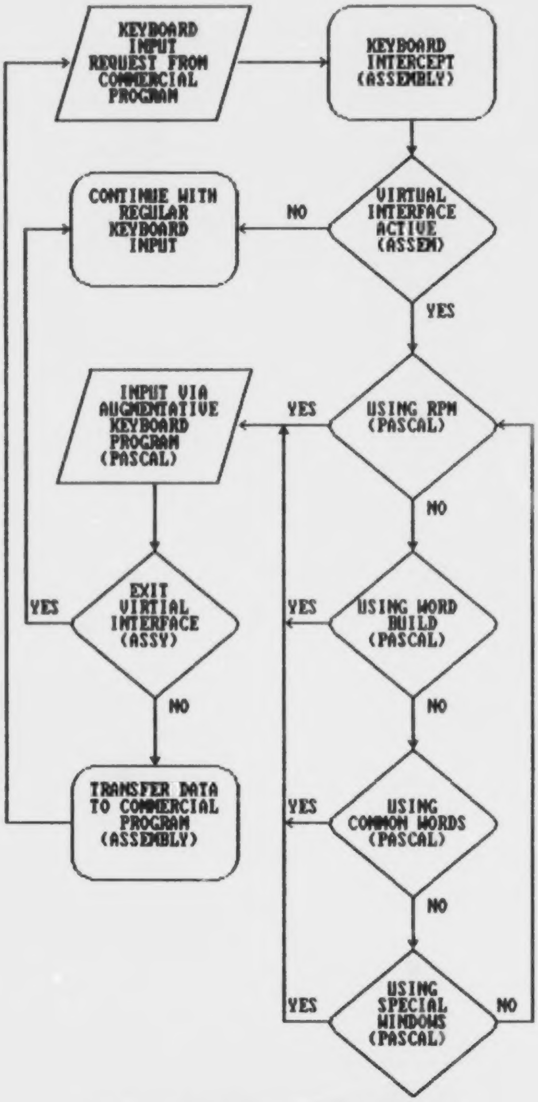

KEYBOARD INPUT REQUEST FROM COMMERCIAL PROGRAM
KEYBOARD INTERCEPT (ASSEMBLY)
CONTINUE WITH REGULAR KEYBOARD INPUT
NO
VIRTUAL INTERFACE ACTIVE (ASSEM)
YES
INPUT VIA AUGMENTATIVE KEYBOARD PROGRAM (PASCAL)
YES
USING RPM (PASCAL)
NO
YES
EXIT VIRTIAL INTERFACE (ASSY)
NO
YES
USING WORD BUILD (PASCAL)
NO
TRANSFER DATA TO COMMERCIAL PROGRAM (ASSEMBLY)
YES
USING COMMON WORDS (PASCAL)
NO
YES
USING SPECIAL WINDOWS (PASCAL)
NO

FIGURE 1 OPERATION OF VIRTIAL INTERFACE MODULE AS A MEMORY RESIDENT PROGRAM CODED IN MICROSOFT MICRO ASSEMBLY AND PASCAL LANGUAGES

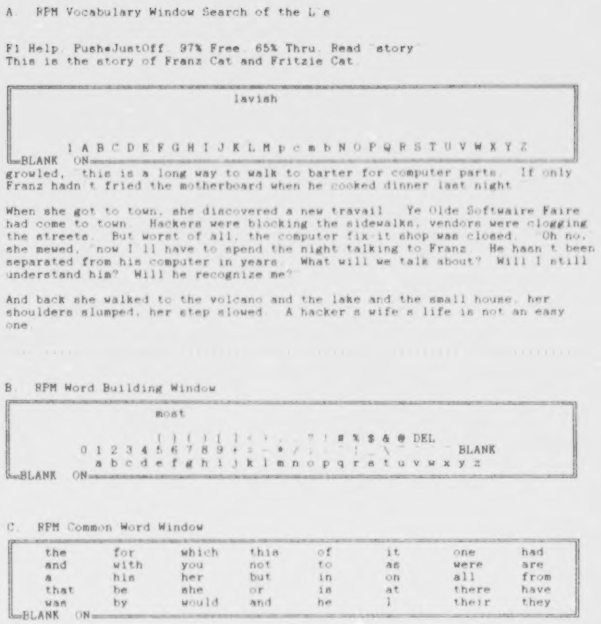
The disabled person can now operate almost any software package that able bodied coworkers are using. The RPM system (2) has been incorporated within the VIM (Figure 2). This provides the user with a 30,000 word dictionary which can be rapidly scanned for the correct word. If the desired word is not in the dictionary it can be built with a build word function. Also, dictionary words can bemodified so that appropriate endings can be added. The 40 most common words used in english writing are also available for quicker access.

A special feature of the VIM is the availability of an unlimited number of linked personalized windows. Each window has forty positions that can either contain a command, a macro, or chain to another window (Figure 3). For a word processor, commands for delete functions, movement of text, and cursor movement would be desirable. Any meaningful sequence of keystrokes can be incorporated. Each of the 40 positions contains two parts. First the mnemonic that appears on the screen, and second, the sequence of keystrokes that represents exactly the action desired as if it were being keyed in from the keyboard. A window authoring software package is part of the VIM. It allows initial creation of a screen or modification of one that already exists.

RESULTS

The normal mode of operation for input on an IBM PC type computer is through the use of hardware and software interrupts using BIOS ROM or MS DOS. The approach used with the VIM is to modify the actions taken when the software interrupt is generated. Rather than taking characters from the keyboard input buffer they are taken from a VIM buffer filled through the alternate input method. A keyboard intercept routine does this. If the VIM is active and data is available in the VIM buffer it is used. If data is not available then the system waits for input from the augmentative communciations portion of the program to enter the VIM buffer where it triggers the appropriate actions to pass the data to the operating program such as a word processor. If the VIM is not active then normal keyboard input occurs.

The VIM is written in Microsoft Macro Assembler and MicroSoft Pascal. The assembly language portion handles the interrupts and any reading of augmentative input systems, the windows, and the RPM system. The MicroSoft combination was chosen because they could be linked into a single software package.



A. RPM Vocabulary Window Search of the L's

```
F1 Help  PusheJustOff  97% Free  65% Thru  Read "story"
This is the story of Franz Cat and Fritzie Cat.

                    lavish

     1 A B C D E F G H I J K L M p c m b N O P Q R S T U V W X Y Z
BLANK  ON
growled, "this is a long way to walk to barter for computer parts.  If only
Franz hadn't fried the motherboard when he cooked dinner last night."

When she got to town, she discovered a new travail.  Ye Olde Softwaire Faire
had come to town.  Hackers were blocking the sidewalks, vendors were clogging
the streets.  But worst of all, the computer fix-it shop was closed.  "Oh no,"
she mewed, "now I'll have to spend the night talking to Franz.  He hasn't been
separated from his computer in years.  What will we talk about?  Will I still
understand him?  Will he recognize me?"

And back she walked to the volcano and the lake and the small house, her
shoulders slumped, her step slowed.  A hacker's wife's life is not an easy
one.
```

B. RPM Word Building Window

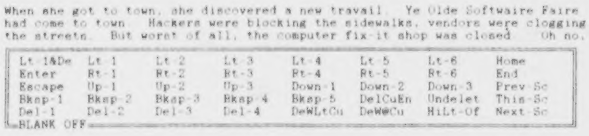
```
                most

                ( ) ( ) [ ] < > , . ? ! # % $ & @ DEL
       0 1 2 3 4 5 6 7 8 9 + = - * / ; : ' | _ \ ~ ` "  BLANK
         a b c d e f g h i j k l m n o p q r s t u v w x y z
BLANK  ON
```

C. RPM Common Word Window

```
  the      for      which    this     of       it       one      had
  and      with     you      not      to       as       were     are
  a        his      her      but      in       on       all      from
  that     be       she      or       is       at       there    have
  was      by       would    and      he       I        their    they
BLANK  ON
```

FIGURE 2 Example of RPM Window Overlays on PC-Write



```
When she got to town, she discovered a new travail.  Ye Olde Softwaire Faire
had come to town.  Hackers were blocking the sidewalks, vendors were clogging
the streets.  But worst of all, the computer fix-it shop was closed.  "Oh no,
 Lt-1&De  Lt-1     Lt-2     Lt-3     Lt-4     Lt-5     Lt-6     Home
 Enter    Rt-1     Rt-2     Rt-3     Rt-4     Rt-5     Rt-6     End
 Escape   Up-1     Up-2     Up-3     Down-1   Down-2   Down-3   Prev-Sc
 Bksp-1   Bksp-2   Bksp-3   Bksp-4   Bksp-5   DelCuEn  Undelet  This-Sc
 Del-1    Del-2    Del-3    Del-4    DeWLtCu  DeW@Cu   HiLt-Of  Next-Sc
BLANK OFF
```

FIGURE 3 Example of a VIM 40 Position Window with Editing Commands for PC-WRITE

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A PROTOTYPE EXPERT SYSTEM FOR THE DESIGN OF A VISUAL KEYBOARD

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INTRODUCTION

Visual keyboard

A *visual keyboard* replaces the standard keyboard with a graphic representation displayed on a computer screen as part of an alternate access system for physically disabled persons to control computers. Items on the visual keyboard are selected through scanning or pointing techniques that use input devices such as single or multiple switches, joysticks, mice, or head pointers (optical or ultrasonic). These items may consist of alphanumerics, words, phrases, symbols or pictures and are referred to as a *selection set*. They may be defined in terms of:

- *Content:* the meaning or concept of each item
- *Representation:* how the content of an item is represented in the visual keyboard, eg. English text, Blissymbols, or pictures
- *Presentation:* how the representation of an item is actually displayed, eg. size, font, location, spacing, colour etc.

There are several commercially available computer access systems that incorporate this visual keyboard concept, including the MOD Keyboard™(1), Adaptive Firmware Card™(2), PC A.I.D.™(3), and Mac•Keyboard™(4).

The problem

When the Elementary MOD Keyboard™ (5) (EMK) was first introduced in 1985, it quickly became apparent that flexibility in the customization/design of a visual keyboard posed problems. The EMK has the capability of displaying on a full-size screen any number of letters, words or phrases, arranged in any order. However, the people responsible for its customization – clinicians, teachers and parents, did not exploit the flexibility available in designing displays, appropriate and optimal for the user. It was similar to giving a canvas and a paintbrush to someone – if they were an artist they could fill it, if not, they would not know where to begin.

Some general rules for layout were suggested in the documentation but a systematic design process was lacking. The key problem was the matching of the many possible combinations of layout features with the user's skills and needs. These features include: lines per page, items per page, number of pages, location of items (horizontal, vertical, and page), label representation, and item definition.

While present access systems such as the EMK are powerful and flexible, they use primitive display technology. New computer displays capable of high resolution where full typographical and graphic control is possible are now available. Mac•Keyboard for the Macintosh™ computer takes advantage of some of these display features, and it is hoped that future visual keyboards will exploit these capabilities to their fullest. Unfortunately, more flexibility will require further decisions to be made by a person not trained in typography, graphic design or human factors.

METHOD

The approach

To help design visual keyboards, a prototype computer-based expert system has been constructed that embodies a systematic *design process* and relevant knowledge of experts relating to visual displays. The expert system acts as an intelligent assistant, guiding a clinician in defining the *content* and *representation* of the selection set through an analysis of the application requirements and the user's skills and needs. An appropriate visual keyboard *presentation* is then suggested by the expert system that satisfies the user and application needs.

Design process

A multiple-stage design process has been adapted from abstract models of human-computer interaction proposed by several authors (6, 7, 8). This model is composed of 5 stages: task analysis, conceptual design, semantic design, syntactic design, and lexical design. A sixth component, pragmatic considerations straddles all of the stages. The expert system is being designed to support the design process in an interactive and dynamic fashion with the system visually showing the development of the visual keyboard. While the following stages are presented in sequential order, actual design is iterative.

Task analysis is concerned with the requirements of the application program to be accessed and the skills of the user. It is assumed that the user's perceptual, cognitive, and motor skills have already been assessed and that a selection technique and corresponding input device has been determined. The pragmatics of the interaction between the user and the visual keyboard through a selection technique are also delineated. These pragmatics are considered in all of the stages and are especially important when the mapping between a visual keyboard item and its related function in the application is obscure, eg. when a single item maps onto a sequence of complex actions in the application.

The *conceptual design* deals with defining the user's conceptual or mental model (9) of themselves controlling an application through the visual keyboard. By forming a conceptual picture of the user's perception of the interaction in advance, consistency within the visual keyboard can be ensured. Conceptual issues include: representation of items, level and style of control, and function of the visual keyboard with respect to the application. Bounds on the conceptual model include the selection technique and the level of integration possible with the application's own interface.

The *semantic design* deals with the functionality and meaning of the interaction. The prime issue is the meaning behind the content of the visual keyboard. All relevant inputs and functions that have been identified through the task analysis must be mapped consistent with the conceptual model for the user.

The *syntactic design* refers to the elements of control and the order of events within the visual keyboard. Items are organized to simplify visually locating an item as well as selecting that item. Group and order attributes are associated with all keyboard items and items are usually categorized according to some functional or semantic relation.

The *lexical design* describes the specific items and their presentation properties such as text font, style and size, location, and visual embellishments. Associated with this is the specification of the exact data sent to the application from the visual keyboard.

Clinical knowledge

Clinical knowledge has been gathered through interviews with occupational therapists and augmentative communication consultants who have experience in creating communication displays and visual keyboard systems for specific clients. This knowledge relates to: the user skills required for visual keyboard use; measures of these skills; user constraints; primary visual keyboard features of concern; and relationships between skills and features. For example, user skills are typically described in relation to two goals – locating the target item and getting to the target item. The primary skills used to accomplish these goals include:

- *visual-perceptual* – discriminating/contrasting different stimuli, matching, sequencing, maintaining gaze, scanning, and integration with motor function
- *cognitive* – language-representation system, reading ability, short-term memory, sequential memory, choice-making, linking visual representation and meaning of item, and categorization/classification ability
- *motor* – range of movement, resolution of control, fatigue, timed activation and timed release in movement control

RESULTS

A prototype expert system has been implemented on a Macintosh Plus™ within an ExperCommonLisp™(10) environment. Through the use of the expert system, a clinician is able to create a visual keyboard, similar to Mac•Keyboard, with total freedom to incorporate any available presentation feature on the Macintosh. While the system does not presently create a visual keyboard that can be used with any application, it will generate a file that can be used by Mac•Keyboard after some compilation. Clinical evaluation of the prototype expert system remains to be completed.

Of particular difficulty was the handling of imprecise descriptors of skills which are typically described in functional terms. This functional description typically necessitates some trial and error testing which can be time-consuming. The system attempts to minimize this by exploiting expert judgement to suggest a limited set of likely functional abilities that can be tested based upon more general skill descriptors. Decision-making based on imprecise rules and data utilizes an approach applying interval-valued fuzzy sets (11) being developed at the University of Toronto.

CONCLUSIONS

It is recognized that the custom design of a visual keyboard that matches the skills and meets the needs of a physically disabled user is very difficult. A design process has been proposed that provides a consistent systematic approach. This process has been incorporated into a prototype expert system that embodies knowledge gained from clinical experience in the rehabilitation field, and knowledge from human factors research and graphic design principles. It is hoped that this system will provide a foundation upon which to improve our ability to customize access systems for physically disabled persons.

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ACCESSIBILITY OF OS/2 FOR INDIVIDUALS WITH MOVEMENT IMPAIRMENTS: STRATEGIES FOR THE IMPLEMENTATION OF 1-FINGER, MOUSEKEYS, AND SOFTWARE KEYBOARD EMULATING INTERFACES USING DEVICE DRIVERS AND MONITORS

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ABSTRACT

The Microsoft/IBM Operating System/2 (OS/2) offers new advantages in accessibility over PC-DOS in the implementation of special software, such as 1-FINGER, MOUSEKEYS, and Keyboard Emulating Interfaces (KEI), to allow individuals with movement impairments to use the computer. OS/2 accomplishes this by providing a better means to simulate user input of the mouse and keyboard. First, application programs must get user input via the operating system kernel rather than directly via the hardware. In turn, the OS/2 kernel relies on device drivers instead of interacting with the hardware to get user input. Therefore "fake" user input for the operating system kernel and the application programs can be achieved by re-writing the device drivers to provide the functionality of the special input software. OS/2 also provides a facility called "monitors" which allows programs or "processes" to monitor the data stream of a device driver in a manner so that the monitor can either remove, insert, or modify the information passing through the device. In addition, since OS/2 provides true pre-emptive multi-tasking, it allows these alternative input programs to run concurrently with the application programs without interfering with them or other monitor programs.

However, there are some restrictions imposed with OS/2. A monitor is limited to a screen group, which means that if an alternative input program is to work in all the screen groups, then monitors need to be registered in each group. Another restriction is that programs which run in the OS/2 compatibility box will not be able to benefit from the alternative access programs that use monitors or rely on the multi-tasking ability of OS/2 since both the monitors and the multi-tasking processes are halted when running a program in the compatibility box (necessary if you want to run standard PC-DOS programs). This means that the only way to get alternative access programs to work with OS/2 in both the protected mode and the compatibility box will be to re-write device drivers.

Nevertheless, OS/2 provides a much better environment to implement special input software than the method of using terminate-and-stay-resident (TSR) programs in PC-DOS, where the TSR's constantly collide with each other over control of the hardware and user input, and where application programs would access the hardware directly.

INTRODUCTION

Microsoft/IBM Operating System/2 (OS/2) is a very complex operating system. There are many new concepts and terms that need to be understood before effective discussion on the merits and problems of OS/2 in regard to accessibility by individuals with disabilities can take place.

Protected Mode Operation

OS/2 utilizes the protected mode capability of the Intel 80286 microprocessor. In this mode, the processor is able to support true pre-emptive multi-tasking. Pre-emptive means that even if a program wants to keep control of the CPU execution, it cannot. Programs are forced to share CPU time with other programs running at the same time without even being aware of the switching.

Process

An application program is one "process", which may have several threads running at the same time, and may have ownership of resources such as the screen and serial ports. There can be more than one instance of a program running at a time (i.e. two instances of a Lotus 123 program running). Then each instance of the program is a different process, with only one copy of the code in memory.

Threads

In protected mode, the processor can run different pieces of code all at the same time. In reality, it is only running a "thread" of code at a time, but threads are stopped and started based on a priority system in a preemptive manner..

Screen Group

Program(s) run in a "screen group." Programs in each screen group send screen output to a virtual screen and get user input from a virtual keyboard and mouse. The screen group which is "active", displays its output on the physical display and the input from the physical mouse and keyboard get directed to it.

Compatibility Box (real mode operation)

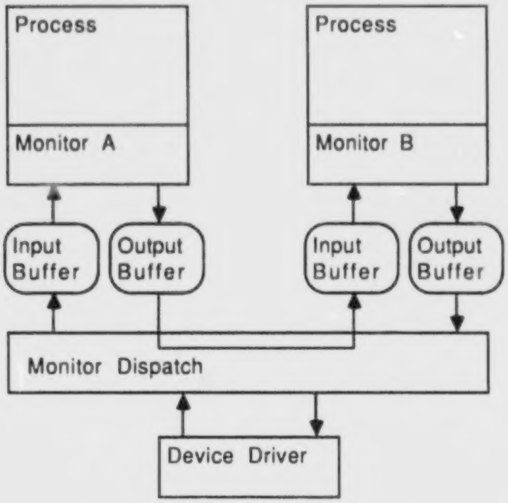
The "compatibility box" is where real mode DOS applications can be run and it is itself a screen group. While in the compatibility box, all protected mode screen groups are inactive, and likewise, while in the other protected mode screen groups, the program running in the compatibility box is inactive.

DISCUSSION

Because of the structure of OS/2, there are many different approaches to implementing programs such as 1-FINGER, MOUSEKEYS, and a software KEI, and to gaining different levels of accessibility.

Monitors

OS/2 provides a feature called "monitors" which allow programs to register a piece of code that monitors the data flow of a device driver. The device driver passes on data to the "monitor dispatch" unit. This unit passes the data to the input buffer to a monitor. The monitor then gets the data packet from its input buffer, and can either do nothing and write it to the output buffer, can inhibit it by not writing it to the output buffer, or can modify it and write it to the output buffer. The monitor, since it is another thread, can also actually write a data packet into its output buffer anytime, even if it never received a data packet from its input buffer. In this way, it can inject data packets. The monitor dispatch unit (it is also an another thread) simply takes data packets from the output of the monitor and either passes it on to another monitor (if there is another one) or passes it on to the system.



If there is more than one monitor attached to a device driver, then they are passed the data packets from the device driver in the order that they are registered. Therefore, for a program like 1-FINGER which needs to be the very first monitor that gets data packets from the device driver, it needs to always be the first monitor. Other monitors that provide functions like keyboard macros, or MOUSEKEYS can be in other positions. A monitor that only injects data packets, such as a KEI, must go before keyboard macros or mousekeys, and after a 1-FINGER monitor.

Device Drivers
To allow OS/2 to run on different hardware platforms, OS/2 depends on device drivers. OS/2 has a defined protocol between the device driver and the operating system kernel, so the underlying hardware can be different as long as new device drivers are written for them which support the minimum features of the standard device, and conform to the established protocol.

This helps in providing alternative access since the kernel does not know if the actual data passed from the device driver was really generated from the hardware or not. In addition, there is also the ability for a program to communicate with a device driver, and so a program could pass "simulated" data to the device driver. The next time the device driver is asked for data, it can pass on the simulated data instead of real data.

Advantages Over PC-DOS
OS/2 has the advantage over PC-DOS in that there is a much clearer and less catastrophic way for more than one program to not only reside in memory at the same time, but to be executing intermixed, without cooperative pseudo-multi-tasking.

OS/2 also provides an orderly was to hook into the data path of input devices such as the keyboard and the mouse. There is no longer this need to be careful of the order of loading TSR programs.

OS/2 also provides ways to inject multiple events into the data stream of a device driver. In PC-DOS, it was impossible to simulate new or different keystrokes for the keyboard interrupt since the keyboard interrupt routine looked directly at hardware.

OS/2 also provides strict guidelines such that other programs can't disable the access programs.

Disadvantages Compared to PC-DOS
A disadvantage of OS/2 as compared to PC-DOS is that the main features of OS/2 (e.g. multi-tasking, monitors, etc.) are not available in the compatibility box. Therefore, any solution which relies on the protected mode features of OS/2 will not work in the compatibility box, and the traditional PC-DOS approaches will have to be used. However, these approaches may no longer work since programs which are timing dependent, "know" something about DOS, or write to absolute hard disk location will not run. Unfortunately, this includes many of the current access programs.

CONCLUSION

Since Microsoft/IBM Operating System/2 is a completely new system, the old access programs that worked under PC-DOS no longer work. However, OS/2 does provide some much needed features that make alternative input programs much more effective and easier to implement in the future. Except for PC-DOS programs which must run under the compatability box, simulation of all the input devices are possible and in an easy manner. Providing complete access in the compatibility box requires the difficult task of re-writing device drivers. Overall, OS/2 makes the days of the battles between terminate-stay-resident programs of the PC-DOS days a problem of the past.

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A SIMPLE MATHEMATICAL ANALYSIS OF HEAD MOVEMENT

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INTRODUCTION There are many instances of head based control of devices of a widely varying nature. In recent years two examples of the success of this approach are the Lighttalker and the Personics head control for the Apple Macintosh Computer. Aside from the quality of the software that runs with these two devices they represent two interesting approaches to monitoring head position. The sensor of the Lighttalker provides an obvious indiction of the pointing direction for this device and can be manually adjusted for best performance. In addition the electronics can integrate the signal to improve efficiency where there is associated tremor [1]. The Personics head control exploits the mouse drivers on the Apple Macintosh to continuously update the sensor's calibration by 'sticking' the cursor at the edges of the screen. Further the Macintosh is able to use a velocity component to introduce non linearity between the head position and the cursor position, thus cursor position is dependent upon both head orientation and angular velocity.

This paper describes the mathematics for represent head positions and gestures and suggests some simplifications to allow practical use.

COORDINATE TRANSFORMS Full analysis of head position requires determination of a coordinate frame fixed in the head with respect to other frames. Use of a 4 · 4 matrix to represent position and orientation is one simple and well documented method. Coordinate frame B is completely described in terms of frame A by a vector $\mathbf{p}$ to the origin and three unit vectors $\mathbf{n}$, $\mathbf{o}$ and $\mathbf{a}$ directed along the x, y and z axes respectively (figure 1). This is expressed in matrix form, together with the inverse, as follows.

$$
{}^{B}T_{A} = \begin{pmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{pmatrix}
\quad
{}^{A}T_{B} = \begin{pmatrix} n_x & n_y & n_z & -\mathbf{p}.\mathbf{n} \\ o_x & o_y & o_z & -\mathbf{p}.\mathbf{o} \\ a_x & a_y & a_z & -\mathbf{p}.\mathbf{a} \\ 0 & 0 & 0 & 1 \end{pmatrix}
$$

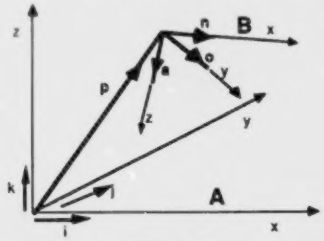

Figure1

Vectors in frame A can be transformed to frame B by premultiplying by ${}^{A}T_{B}$. Relative transforms across several frames are achieved by successive multiplication of the transforms of the intermediate frames. Thus if ${}^{C}T_{B}$ is the transform of C in the B coordinate frame and ${}^{B}T_{A}$ is the transform of B in the A frame ${}^{C}T_{A} = {}^{C}T_{B}{}^{B}T_{A}$.

TRANSFORM GRAPHS Figure 2 shows an arrangement of coordinate frames based on a seated figure. For convenience the coordinate frame of a Polhemus source unit is taken as a base frame. The Polhemus sensor coordinate frame is shown in the figure and represented by T_{pol}, values of T_{pol} are obtained directly from the Polhemus system. A head coordinate frame is defined in terms of the sensor frame by T_{head}. An observer frame, usually representing the position of a computer or symbol board presented to the person, is given by T_{obs}. Additional transforms are defined as the sacrum in the base frame (T_{sacrum}), the first thoracic vertebra in the sacrum frame ($T_{thoracic}$) and head frame in the thoracic frame ($T_{cervical}$). T_{sacrum} and T_{head} are assumed to remain constant while head position is monitored. $T_{cervical}$ contains information about gestural data while $T_{pol}T_{head}$ can be used to calculate direct pointing data.

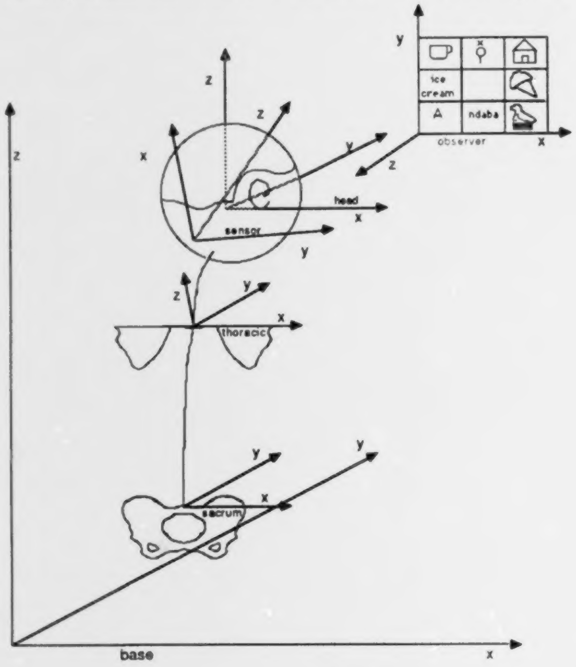

Figure 2

A transform graph is shown in figure 3. The relationship between any two coordinate frames is given by tracing from the arrow head of the given coordinate frame to the arrow head of the required frame, taking a transform 'against' the direction of arrow as its inverse. Thus the transform of vectors from the head coordinate frame into the observation frame is given by $T_{head}^{-1}T_{pol}^{-1}T_{obs}$

SPINAL ANATOMY Head position can also be estimated from a simple model of a person in a seated position. If a person is seated, supported by their pelvis and legs, the spine may then account for a wide range of angular movement. 'Yes' and 'No' gestures are identified by the movement of the person's head with respect to their shoulders.

The spine itself can be modeled as a fixed length arc of length L and gross spinal movement is assumed to occur between the sacrum joint and the first thoracic vertebra. For simplicity it is assumed that the scapulae remain in a fixed position with respect to this vertebra, a reasonable approximation since the arms will probably remain below the persons shoulder level. Assuming the z axis remains continuous with the direction of the spine at T1 and there is no shoulder rotation during movement, $T_{thoracic}$ is given by

$$\begin{pmatrix} \frac{\cos 2\beta}{\eta} & \frac{-\sin\alpha\cos\alpha\sin^2 2\beta}{\eta} & \cos\alpha\sin 2\beta & \frac{L\cos\alpha(1-\cos 2\beta)}{2\beta} \\ 0 & \frac{\cos^2 2\beta+\cos^2\alpha\sin^2 2\beta}{\eta} & \sin\alpha\sin 2\beta & \frac{L\sin\alpha(1-\cos 2\beta)}{2\beta} \\ \frac{-\cos\alpha\sin 2\beta}{\eta} & \frac{-\sin\alpha\sin 2\beta\cos 2\beta}{\eta} & \cos 2\beta & \frac{L\sin 2\beta}{2\beta} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

where $\eta = (\cos^2\alpha\sin^2 2\beta + \cos^2 2\beta)^{1/2}$. α and β are given in spherical polar coordinates where $r = L\sin\beta/\beta$, β is measured from the z axis and α is the projection in the x y plane from the x axis. The section of spine between T1 and C1 is assumed to be responsible for gestural head movement. Head movements in the horizontal plane are due primarily to movement between the atlas and axis (C1 and C2 vertebra) while movements in the sagital and lateral plane are assumed to be spread over the length of the cervical spine.

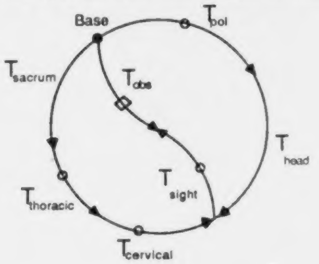

Figure 3

HEAD POINTING EQUATIONS Assume that the direction of head pointing is given in the head coordinate frame by the direction cosines $[v_x v_y v_z 0]$. These are either taken as constant or calculated from eye position by a device such as the MicronEye [2]. If the latter approach is used problems may be encounted when defining the sensor origin. However, provided absolute line of gaze is not required, any errors should be compensated in the self calibration. Since the transform T_{sight} converts vectors from the head coordinate frame to vectors in the observer frame, if the plane containing the screen cursor is chosen to be $z = 0$ then a vector of length w in the head coordinate frame, parallel to the direction cosines, can be drawn to intersect this plane. This vector can be transformed to the observer frame so that the x y position of eye gaze intersection is

$$\begin{bmatrix} x \\ y \\ 0 \\ 1 \end{bmatrix} = \begin{pmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{bmatrix} \frac{v_x}{w} \\ \frac{v_y}{w} \\ \frac{v_z}{w} \\ 1 \end{bmatrix}$$

Thus $w = -(v_x n_z + v_y o_z + v_z a_z)/p_z$ and values for x and y can be calculated.

GESTURE EQUATIONS The transform graph can also be used to obtain the differential changes. The Δ transform is defined by the equation $dT = \Delta T$ and describes a differential rotation and translation of $\delta_x\delta_y\delta_z d_x d_y d_z$. Since the rotations and translations are small this transform is independent of order.

Since both the head and the thoracic frames are of interest Δ is calculated for both. The changes to the head frame are calculated in terms of movements of the Polhemus sensor as ${}^{head}\Delta = T_{head}^{-1}\,{}^{pol}\Delta T_{head}$. This corresponds to movements in the sagital and horizontal planes or, if pure rotation, 'Yes' and 'No' gestures. The second transform relates the changes to the thoracic frame for which ${}^{thoracic}\Delta = T^{-1}\,{}^{pol}\Delta T$ where $T = T_{pol}^{-1} T_{sacrum} T_{thoracic}$ By comparing ${}^{thoracic}\Delta$ and ${}^{head}\Delta$ effects of gross spinal movement can be eliminated from meaningful gestures.

An alternatively method of eliminating gross movements from meaningful gestures is to calculate the transform $T_{cervical} = T_{thoracic}^{-1} T_{sacrum}^{-1} T_{pol} T_{head}$. The elements of this matrix can be converted to an equivalent angle of rotation around a unit vector. This gives the head position with respect to a resting position compared with the changes of head movements given by the previous method.

When solving these equations it is helpful to make some simplifications. If the axes of the observer frame, the sacrum and the base frame are aligned and unchanged during the period data is gathered only the **p** vectors are unknown and can either be measured or calculated at the start of a session. T_{head} depends only on head size and sensor position so can either be calculated before a session or looked up in a data base. finally values of α and β in $T_{thoracic}$ can be estimated from the x y position of the Polhemus sensor.

SELF CALIBRATION The principle of 'sticking' cursor can be achieved by changing the **p** vector in T_{obs}. If the axes of the base and observer frames are parallel and as shown in figure 2 and the x y position of gaze lies outside the screen the **p** vector is updated as follows.

$$p'_x = \begin{cases} p_x + x_{sight} - width & \text{if } x_{sight} > width \\ p_x + x_{sight} & \text{if } x_{sight} < 0 \end{cases}$$

$$p'_z = \begin{cases} p_z + y_{sight} - height & \text{if } y > height \\ p_z + y_{sight} & \text{if } y_{sight} < 0 \end{cases}$$

finally p'_y is readjusted so $p'_y = \sqrt{(\mathbf{p}.\mathbf{p} - p'^2_x - p'^2_z)}$ sensitivity can be increased by reducing the magnitude of **p** as this effectively brings the screen closer to the subject.

CONCLUSIONS coordinate transforms are a convenient method for presenting head position data with out losing information. Where time is a critical element the matrices would be used to simply derive the necessary equations at the expense of flexibility. No consideration has been given to practical computation of these transforms but some have been implemented on an IBM compatible AT in real time. In addition to gestural and pointing information the transforms can be used to check intersection with any arbitrary plane thereby becoming a rather expensive virtual switch.

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HUMANCAD Human Models for Computer Aided Design

William W. Belson III

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Human Models For
Computer Aided Design
by: William W. Belson III

INTRODUCTION

The designer is faced with a wide range of problems when creating equipment, space and environments that have human interfaces. These problems are compounded when the special needs of the disabled are introduced. In order to create a successful design, knowledge of human parameters, limitations and measurements is required. Resources such as HumanScale (1), Human Factors Design Handbook (2), and Human Body in Equipment Design (3) have compiled these statistically weighted composites. Armed with this knowledge, the designer can create and position equipment to meet the needs of a targeted group.

The past five years has seen a revolutionary tool become available to almost every designer. Personal computer (PC) based computer aided design (CAD) software has given designers the ability to explore several variations in a fraction of the time required to manually create a single design. In designing for the disabled this allows necessary customization of a standard design in a very short period of time.

HumanCAD is a computer program that works with AutoCAD (4) computer aided design software. It is a series of human component shapes that can be individually manipulated within a design, giving accurate representation of how a targeted population section will be accommodated.

AutoCAD contains a powerful programming language imbedded within the overall software. This is a version of LISP (5), which is held in much esteem as an artificial intelligence language.

HumanCAD is a combination of scaled statistical drawings and an AutoLISP (6) program. It is menu driven and is added to the standard AutoCAD menu.

Utilization

When the designer reaches the point in the drawing where human measurement feedback is desired, the HumanCAD selection on the menu is chosen. The designer has several choices. First is the scale of human figure desired. Presently, full, half and quarter scales are supported.

Next choice is which statistically determined human figure size meets the targeted user. Adult figures have 2.5%, 50%, and 98.5% sizes while children (ages 1,2,4,6) and adolencent (ages 12,14,17) figures are only available in 50% form. The percentile represents the statistically determined portion of the population whose measurements are at or below this value. Each percentile figure has a two dimensional top, side and front view available.

Manipulation

Each individual member of a figure can be pivoted about a joint to fit the figure into the drawing environment correctly. Disabilities can be simulated by moving the appropriate member into the simulated position. Amputees can be simulated by removing the corresponding member on the figure. If a member is being rotated about a joint in an unnatural extension, the program informs the user of the 'normal' range of motion.

Once positioning is finished, the program calculates the positioned figures effective center of gravity in the plane shown. When a modification is made, such as repositioning a child's head to simulate low celebral tone, the effective center of gravity is recalculated.

Example
A designer creating a new wheelchair has drawn a full scale sideview. Before investing more time, verification of certain critical component locations is needed. Deciding that a 50% male model adequately represents the intended user, the designer chooses '50% Male Side View' off the HumanCAD menu. He inserts the model into his drawing. The program prompts in as to how he wants the model's foot, leg, thigh, arm, forearm, hand and head positioned. It also asks if the field of vision should be shown. Once the model is positioned, HumanCAD calculates and displays the effective center of gravity.

Deciding to check the location of the legrest pivot, the designer rotates the the legrest 90 degrees to full extension. He then picks 'Model Reposition' command from HumanCAD, chooses the foot and leg as the members to reposition, and specifies the amount of rotation. The members are moved and the revised center of gravity is calculated and displayed. The designer can graphically see if the pivot location is correct, and the reaction of the center of gravity to the model being in the new position.

CONCLUSION

HumanCAD allows the designer to explore options involving human form quickly and easily. It gives valuable engineering data on the effect of these options for static and dynamic stability. It allows the simulation of positions caused by disabilities. These are very important tools necessary in creating a successful and effective design. They can help the successful designer in his goal to improve the quality of life.

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THE APPLICATION OF COMPUTER BASED WORKSTATIONS FOR VOCATIONAL REHABILITATION

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INTRODUCTION

Successful vocational placement of disabled people is one of the most important goals in the rehabilitation process. Wright [1] identified the importance of engineering input as part of a team approach. in addition to increasing a disabled individual's general functional capacities through technical aids, engineering principles can be applied to specific problems encountered in potential jobs. A wide range of worksite adaptations have allowed many disabled people to attain gainful employment. These range from simple mechanical adaptations to industrial workstations [2], to the use of robotic manipulators as a way to achieve flexible accomodation to the worksite [3].

To a large extent, worksite adaptations are directed at increasing an individual's ability to move objects (e.g., tools, materials). In cases, where individuals have significant motility impairments, this can be a formidable challenge. Fortunately, employment trends in the United States and other countries have created the potential for new vocational opportunities for disabled people.

Information Based Occupations

The U.S. Department of Labor recently published employment projections for the year 2000 [4]. While the goods producing sector will actually experience a small decrease in the number of available jobs, the service providing sector will experience a growth of approximately 20 million new jobs. Prominent among this growth is occupations that deal primarily with the manipulation of information. Information based occupations are ideal for many disabled people because rather than manipulating objects that have size and mass they require the manipulation of information. Information has no inherent mass or size, but in general exists in some medium that requires physical manipulation. For example, paper has historically been the most universal means for representation of information.

The advent of electronic technology, most importantly computers, has played a significant role in the manipulation of information in the last decade [5]. This has created many new jobs in support of the technology (e.g., computer programmers), and has changed the nature of existing jobs (e.g., typist -> word processor). Given the successful efforts to make computers accessible to physically disabled people, computer based occupations hold great promise.

The Problem

This promise has not been fully realized for a number of reasons. Computer based occupations like other occupations have a wide range of requisite skills and abilities. Consequently, there are many occupations that are not appropriate for a large part of the disabled population. For example, word processing can be viewed as an *inappropriate* occupation because it requires a significant proportion of physical effort. Typing rates of 60 words per minute are not uncommon in this occupation.

In contrast, computer programming has been viewed as an *appropriate* occupation because the individual must spend a significant amount of time thinking about a program and relatively little time actually typing it in. In fact, many successful results have been demonstrated in this area [6,7]. Unfortunately, programming and other *thought intensive* occupations require aptitudes that many people (including many disabled people) do not have. In addition, although computer training programs exist that are relatively short in duration [6], many programming positions require a minimum of four years of university study.

Goal

The goal of this project is to demonstrate the potential of computer assisted technology for occupations that would allow more choices for job seeking disabled individuals. The target occupations would have the following characteristics.

1. Manipulation of information rather than physical objects.
2. Relatively low quantity of information input.
3. Modest academic requirements.

The tangible result of this goal is the identification of a potential occupation and the development of an adapted workstation. This workstation should be designed to eliminate, as much as possible, the physical barriers for job performance.

METHODS

The methods for accomplishing this goal consists of two major components. First a thorough analysis of a job must be performed. Second, an adapted workstation must be developed based on information collected in the analysis process.

Job Analysis

The methods used for job analysis are based on traditional vocational rehabilitation methods [8]. These methods incorporate a number of descriptive and analytical processes for obtaining an understanding of a particular job. One important aspect of this process is the breakdown of a job into component tasks. This task breakdown has been further extended as described in a previous paper by Demasco et. al., [9].

The job analysis serves two major purposes. First, it establishes the feasibility for developing an adapted workstation and identifies potential problems to the process. Second, it serves as a task specification for the design process that will follow if the job is deemed feasible.

System Design and Development

Although the actual design and development of a workstation are specific to both the client's abilities and the task requirements of a specific job, there are elements of this process that merit a general discussion.

Physical workstation - There are two major goals in the development of the physical workstation. The first is to make the computer accessible to the user. The second is to minimize the need to manipulate other physical objects that might normally be part of the job. An example of this is the use of a telephone management board within the computer to eliminate the need for the manipulation of a phone.

Software design - The software has a number of general design goals. First, it should support the job task as completely and as efficiently as possible. This can be accomplished by maximizing the flexibility and efficiency of the user interface. Second, the software should support the second design goal for the physical workstation (i.e., minimal manipulation of physical objects). This goal is embodied, for example, as support for a telephone board and complete on-line documentation.

RESULTS

Two software applications are currently under development in support of two potential occupations. Both of these jobs share many common aspects including use of a telephone, entry of information in structured forms, and a great deal of social interchange.

Telemarketing - Telemarketing as an occupation encompasses a broad range of purposes that extends beyond simply selling products or services. In the most general sense, it involves calling individuals or businesses on the telephone and obtaining information from them. This occupation has been targeted as the major emphasis for this project. Currently, telemarketing has been identified as a feasible occupation, and system design is underway. The software which will run on MS-DOS computers will provide the employee all of the functions needed to perform the job, including telephone dialing, efficient form entry and file management.

Receptionist - A second occupation has been identified for the application of a computer assisted workstation. A major part of a receptionist's job task involve taking telephone messages for employees within a company. Although this is traditionally done on the familiar *While You Were Out* forms, in the adapted setting, the disabled employee would use a computer to perform this job task.

There are many ways in which the computer can provide enhanced efficiency for the completion of message forms. For example, the receptionist need not fill in the time and date of a call. In addition, rather than entering an employee's name, the receptionist can select from a list of choices or simply type in the employee's initials.

CONCLUSION

Although the actual system implementation is not complete at this point, it is anticipated that testing of prototypes will begin in March 1988. The effectiveness of the system will be compared to the performance levels obtained by able-bodied workers (obtained in the job analysis phase). The resulting workstation software will be commercialized and future work will extend to other occupations that will benefit from computer assisted workstations. Work towards increasing the functional capabilities of the workstation will also be pursued, this will include refinements to the software to increase flexibility and the use of new technologies (e.g., CD ROM).

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COMPUTER SIMULATIONS: NEW TOOLS FOR REHABILITATION EDUCATION

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BACKGROUND

A disability simulation research and development program has been initiated, and study of prototype simulations has provided convincing evidence that there is applicability to a spectrum of disability matters. Research findings suggest that such simulations, when properly designed and utilized, can make a substantial contribution to both rehabilitation worker and client education, and disability related research. However, findings have also revealed that careless design or use may produce harmful effects. Descriptions of early projects follow.

PROTOTYPE SIMULATIONS

Wheelchair Odyssey

The objective of this simulation is to provide an interactive experience for students in rehabilitation related occupations that will sensitize them to the spectrum of architectural, attitudinal and other barriers which frequently confront persons with severe physical disabilities. A format similar to that used in computer "adventure games" serves as the basis of the simulation. At the onset of the simulation, the user assumes the role of a person who uses a wheelchair for mobility. The starting point is a rehabilitation center where functional characteristics can be enhanced by purchasing therapy and other rehabilitation related services with available funds.

Once the characteristics are set, the simulation user is able to travel about the "world of disability" in search of "success" by entering appropriate keyboard commands. The individual is confronted with descriptions of obnoxious characters, architectural barriers and other problems which must be dealt with by entering action commands. With each encounter, personal resources are depleted, but may be replenished by returning to the rehab center. If vital characteristics are depleted or the individual makes a critical mistake (e.g., wheeling down a flight of stairs), the outcome is fatal and the simulation ends.

Evaluation has been conducted using graduate students in rehabilitation counseling. It has been concluded that this simulation is most effective when used by small groups of 2 to 4 persons. The small group atmosphere evokes discussion and in-depth exploration of critical concepts, which are often missed during individual use. It has also been observed that some individuals become extremely frustrated because of the difficulty level of the simulation, suggesting that debriefing sessions and supervision are essential to effective use. At this point, feedback is being obtained to determine the concept's potential for helping newly disabled persons to become sensitized to real world problems and to teach them effective coping strategies.

Genesis II

The essence of this simulation is a program segment that creates realistic profiles of persons falling having common types of disabilities. It incorporates functional deficits consistent with specific disabilities, and utilizes randomly selected data falling within realistic bounds to complete the profile. By using random data when possible, no two profiles created by the simulation program are likely to be the same.

At the onset, simulation users are presented with a menu from which to select the type of disability with which they wish to work. Once the disability type is selected and a profile created in memory, the user is presented with several menu choices relating to personal history, consultation/referral, and vocational assessment. Following each selection, the information is presented on the computer monitor, and a printout is provided. The appropriateness of selections is also monitored and feedback is given when choices are inappropriate. Available information ranges from demographics, such as age and residential setting, to reports of medical examinations and tests, and personality inventory profiles.

This simulation has most frequently been incorporated into rehabilitation courses dealing with case management and assessment issues. Although the simulation does not replace the students' need for field experience and other client experience, they are better prepared because it does provide them with increased exposure to realistic client situations.

Long cane mobility simulator
An interactive program was designed to simulate the experience of persons using a long cane for mobility, with particular focus on extent to which long cane use depends upon heightened attention, memory, and aural feedback. The simulation has been designed so that designated keys on the computer keyboard serve as a long cane, enabling the user to probe ahead and side to side while attempting to traverse a simulated metropolitan area.

Users are first given an opportunity to learn the various sounds emitted when the cane tip strikes different surfaces, for examples, concrete, grass, and asphalt. Second, a map of the metropolitan area is presented to the user. There are also moving vehicles on the streets that make a sound when they reach the proximity of the cane user. When the simulation user is familiarized with the map, the monitor screen is blanked, except for a clock showing elapsed time and a tally column that keeps a count of collisions. The user must then proceed from a designated starting point to a finishing point by entering keyboard commands to move or change direction, and relying on memory and the sounds emitted by the "long cane" to determine position.

The findings from an initial evaluation indicate that the simulation is effective in increasing rehabilitation counseling students' knowledge of long cane mobility use. However, other findings suggest that a 1-hour limited experience using the simulation may have a negative impact on attitudes toward blindness. Attitude measures indicated that following use, some students' tendency to pity persons with blindness increased, as well as expression of hopelessness regarding mobility potential of persons using a long cane. Evaluation is continuing to determine the optimal user conditions, with particular concern for impact on attitudes. Additionally, it has become apparent that the concept has potential to serve as a pre-training experience for persons who are severely visually impaired and choose to learn to use the long cane as a mobility aid. A research project is currently being implemented to study this potential use.

CONCLUSIONS

Experience using the three described simulations generally supports the concept's applicability to a wide range of rehabilitation education and research issues. Computer simulations have potential serve as an effective, efficient and life-like training modality for both rehabilitation workers and persons with disabilities. Their use may be most effective when incorporated with traditional training experiences. However, there are also indications that poorly designed simulations or improper use, such as failing to provide adequate support, supervision, or debriefing, may have detrimental effects. Particular attention must be given to the potential impact on the attitudes of users when designing disability simulations and defining the manner in which they are used.

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TRANSPARENT ACCESS TO SOURCES OF COMPUTER-BASED REHABILITATION INFORMATION

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INTRODUCTION

In rehabilitation, the need for accurate and timely information is great. For example, consumers of rehabilitation devices, no matter what their disability, have to know what products will meet their needs. Design engineers have to be aware of the work of their colleagues in order to make efficient use of limited research funds and be aware of the needs of people who would use the new devices. Manufacturers have to form working relationships with developers to insure that the fruits of research reach the marketplace. Health care professionals have to recognize of advances that would increase the quality of life for the patients they serve. And all segments of the rehabilitation community need to interact with each other despite 1) any physical or sensory impairment, 2) geographic separation, 3) rehabilitation speciality, and 4) the possible lack of computer equipment and expertise.

A method of transparent access to computer-based rehabilitation information makes it possible for members of the rehabilitation community without possession or knowledge of computers to obtain existing information and, in general, interact with one another. It does not require the purchase of or instruction in new equipment as it employs only existing and familiar devices. The substantial barriers of having to buy and learn how use a computer for obtaining computer-based information would be eliminated. Both able-bodied and disabled people benefit equally from this type of access. In summary, a system based on the concept of transparent access serves persons who are disabled because of their lack of information and those that are disabled because they lack the funds and time to buy and learn how to use a computer to connect to sources of computer-based rehabilitation information.

Much rehabilitation information is already available on public and private databases or electronic bulletin boards on remote computer systems. This trend towards computer-based information is increasing. However, to reach the information contained in these 'storehouses', the information seeker must 1) employ computer hardware including a modem, 2) be educated in the use of the computer hardware and modem software, 3) be knowledgable of the sources of computer-based information, 4) subscribe or otherwise connect to the particular computer-based information source, and 5) become proficient in the syntax of thoses source(s) of computer-based information in order to formulate a request for the desired information. If these requirements are not met, the desired information can not be acquired. The need to employ computer hardware and software and the substantial knowledge of their use are, therefore, real barriers to obtaining any computer-based information.

METHODS

This project demonstrates methods that increase communication and minimize or eliminate the above equipment and expertise requirements from computer-based information acquisition. The essence of the approach is to employ a centrally located telephone-accessible computer system which 1) engages in a voice output, Touch-Tone input dialog with callers, 2) learns of their information needs, 3) connects to the appropriate information source, 4) transparently acquires the information, and 5) presents it to the caller in voice output format. (Modem communication could also be incorporated, supporting individuals already owning computers, including those with hearing impairments.)

A software program, KIOSK, has been developed that demonstrates how the barriers to obtaining computer-based information can be reduced, benefitting both able-bodied and disabled people.

The KIOSK software has been designed to run on either 8-bit or IBM-PC compatible computer systems. A DECtalk Speech synthesizer completes the hardware complement and provides a friendly interface between the computer and its data and individuals requesting information.

In operation, the user employs his/her home or business Touch-Tone telephone to dial the number of the DECtalk Speech Synthesizer and computer system. The equipment answers the telephone and KIOSK then mediates the interaction between the caller and the computer; speaking to the caller in its synthesized voice while monitoring caller-generated Touch-Tone keypresses. The software 1) permits the DECtalk to speak computer-based text files 2) receives data from the DECtalk on which Touch-Tone keys have been pressed by the caller, and 3) works with a knowledge of a structure for presenting the text information files.

In the current implementation, the interaction between the caller and the computer is accomplished through a series of computer-initiated speech output and caller responses. The user is presented with either instructions, information, or choices. The caller's response to a choice is made by pressing the Touch-Tone key corresponding to his/her selection. The DECtalk recognizes the keypress and causes the program to branch in an appropriate manner based upon the response. This process is continued, with the computer sending information from text files to the DECtalk which are spoken over the telephone and the user making choices on how the interaction is to proceed.

For example, a typical choice might be:

Press 1 for recreational devices,
Press 2 for robotic applications, or
Press 3 for new wheelchair developments.

KIOSK has been developed as a general-purpose program. It operates by structuring disk-based text files, presenting them verbally to the caller at the proper time, when the right sequence of choices has been made. The information provider designs this structure and provides the text files to be spoken by the program. As such, KIOSK is a flexible Authoring System for the DECtalk Speech synthesizer and can be used to disseminate a variety of information.

RESULTS

One current application being demonstrated at this facility is a voice-output version of this Center's 1986 Progress Reports, which are printed descriptions of the operation of the Center and its projects.

When called, the system welcomes the user and briefly describes its operation. After a short introduction to the Center, the user is asked to indicate which of the three groups within the Center (Orthopaedic Biomechanics, Neuromuscular Systems, or Human-Machine Interface) he/she is interested. The user responds with a Touch-Tone keypress and the program branches to the information and projects of the chosen group. The title of a project is then presented and the caller is given the choice of whether to hear the text of the project, go on to the next project, or return to the previous menu of choices.

The KIOSK software has recently been used to create an information system serving blind athletes during their 1987 World Series of Beep Baseball at Ithaca College in New York. Competitors used their telephones to hear team scores and standings as well as information on how to get around campus and the immediate area. Listings of restaurants, shopping areas, bus schedules, and tourist attractions were all included.

DISCUSSION

The next extension of this work will allow a computer system to mediate the exchange of information between the caller and the information contained in remote databases such as CompuServe or computer-based bulletin boards systems. This would be accomplished by first engaging in a dialog with the caller to determine the information required and then connecting to the appropriate information source. Next, the computer would send the required commands in the proper syntax to obtain the information from the remote system and present it to the user as synthesized speech. An electronic librarian would thus be created to transparently search multiple databases of electronic information for the caller.

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DEVELOPING SOFTWARE FOR OCCUPATIONAL THERAPY

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INTRODUCTION

In 1983 the government gifted a number of BBC B microcomputers to various Occupational Therapy Departments throughout the U.K.. At that time, however, there was very little software available which was appropriate for Occupational Therapy (1). A research team was thus set up within the Microcomputer Centre at Dundee University to develop software. The team was interdisciplinary, consisting of engineers and occupational therapists, and the work was conducted in close collaboration with local therapeutic services (2,3).

The treatment areas which were considered in depth were: head injury, psychiatry, paediatrics and functional rehabilitation of physical injury. It was only possible, however, to investigate a small part of the range of therapeutic regimes which may be appropriate for these treatment areas.

The software was designed on the basis of an "operating system" for occupational therapy. In essence this was menu-based and allowed the therapist to set up a number of important parameters in the programs (2). These included the speed at which the program functioned, the level of difficulty of the program, the level of "rewards" and, where appropriate, the choice of interface (e.g. key-board, touch screen, joystick.) The operating system also included "help" functions, and administrative routines for filing, displaying and printing results.

HEAD INJURY

A suit of games programs were developed for head injury patients based on standard games such as "Connect 4", simple arithmetic and spelling games. The programs, however, were designed for a much greater (and lower) ability range than commercial software. By careful choice of levels of difficulties and varying these levels appropriately during treatment, therapists were able to use these games with head injury patients without the dangers of them being demotivated by poor performance.

COGNITIVE REHABILITATION

The software produced for cognitive rehabilitation concentrated on the problems of hemi-neglect. Three important elements were incorporated into these programs: i) strategy training, ii) errorless learning, and iii) maximising positive motivation. The suite of programs included a) shape discrimination tasks, b) reproducing target shapes from subsections of them and, c) visual anchoring tasks. These programs were evaluated by another research group with generally positive comments about their efficacy, and some clear evidence of moderate learning to compensate for the neglect (4).

PSYCHIATRY

The programs developed for psychiatry were developed in conjunction with a psychologist at a State (secure) mental hospital. They were based on "adventure game" principles, and designed to encourage patients to engage in role play, and make decisions. The patients were put into social and domestic situations (e.g. meeting a person of the opposite sex) and asked, via a multiple choice questionnaire, to make decisions as to what actions they would perform

Patients were surprisingly enthusiastic and well motivated by the exercise. The therapeutic advantage of the technique was that patients were willing to discuss both the game and the strategies they had used with attendant clinicians. The clinicians were thus able to raise issues with the patient which they had previously not found possible. In this application the computer acted as a very useful facilitator for therapy rather than being inherently therapeutic itself.

FUNCTIONAL REHABILITATION OF PHYSICAL INJURY

The programs which were developed for functional rehabilitation of physical injury concentrated on hand injury, in particular flexion, extension, pronation, and supination. A transducer was constructed based on a central shaft onto which different handles could be mounted. The position of the shaft was fed into the computer to provide control signals for simple tasks such as simulated car driving and bat and ball games. Calibration of the amount of movement of the handle required was adjustable within the software, and results could be stored. Initial work with this system proved successful and, on the basis of these results, a separate project was initiated for a detailed investigation and software development for upper limb rehabilitation (5).

PAEDIATRIC

Programs which have been developed for children include ones to encourage pre-reading skills such as visual tracking and shape discrimination, using a touch screen interface (6), and some drawing programs for children with severe physical dysfunction.

Content free maze games with detailed performance monitoring were also developed for this group of clients. Extensive use of an "alter" menu enabled the therapist to choose the level of complexity and they could develop their own mazes.

Our software was designed to store,in some detail, the clients responses as they moved round the maze. These were encoded as either i) an illegal move (e.g. the key which had been struck was not designed to be used in the game), ii) an invalid move (e.g. one which would run into a wall), iii) a successful move (i.e. completing the maze), iv) failure, or v) simply a movement within the maze which may or may not lead to eventual success. The software had a real-time recording capability that recorded the events (as specified above) and also the times at which they occurred.

At the end of a session, the results from clients could be displayed for the therapist to examine or printed out for record keeping purposes. The displays of results which have been developed proved useful in illustrating particular performance characteristics, but they have not yet provided significant new diagnostic information. Further research is necessary on the design of such displays.

EVALUATION

The programs which have been described were developed in close co-operation with the appropriate clinics, and were trialled with clients during this development phase. It is notoriously difficult to evaluate the effectiveness of any therapy, and computer assisted therapy is no exception. We are conducting, however, a detailed evaluation of the use of software within occupational therapy clinics, and the results from these studies will be reported at the conference.

CONCLUSIONS

Software for the U.K. BBC B computer has been developed for a range of activities within Occupational Therapy. Clinicians have been involved at all stages in this development, and care has been taken to ensure that the quality of the software is high. The software has proved popular both with clinicians and with clients. An assessment phase is under way which will give a clearer perception of the value of the use of techniques of this nature within occupational therapy clinics.

ACKNOWLEDGEMENTS

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ADAPTED COMPUTER SERVICES WITHIN AN OCCUPATIONAL THERAPY PROGRAM FOR MULTIPLE SCLEROSIS

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ABSTRACT

Adapted computer access needs for the multiple sclerosis (MS) population were identified for the accommodation of severe ataxia and visual deficits, a symptom configuration that severely limits participation in activities of daily living. Within an existing Occupational Therapy (OT) program adapted computer services were begun. A review of the first seven months found: 1) Commercially available products can accommodate the severe ataxia and visual deficits of MS; 2) Adapted computer use, for those severely disabled, provided meaningful activity which could not be achieved through conventional rehabilitative means; 3) Computer use provided a gradable occupational therapy treatment media, valued by adult clients; 4) Technology was introduced to clients whose needs could extend beyond computer use; and 5) Capital expenditures were small relative to revenue. Applicability as an occupational therapy service, benefit to clients, and relatively low startup costs, should encourage other occupational therapists to expand services into the arena of adapted computer access.

INTRODUCTION

Many computer modifications allowing access for the disabled are now on the market, but bridging products with the disabled end-user is dependent on a relatively small number of facilities in the U.S. This service could be appropriately provided by many existing Occupational Therapy Departments.

STATEMENT OF THE PROBLEM

Multiple sclerosis (MS) is an adult-onset, typically progressive disease of the central nervous system, marked by exacerbations and remissions. It varies from benign to rapidly progressive. Life span is not affected.

Three out of ten persons with multiple sclerosis have disability so severe as to lose the ability to walk and the ability to work [1]. This results in an enormous amount of unproductive time, increasing dependence on others and a concomitant loss of self-esteem.

Occupational therapy (OT) focuses on maximizing independence in self-care, productivity, and leisure pursuits. The needs of those severely disabled by MS, estimated at 20% of those referred to O.T. at The Mellen Center, were not being met by traditional rehabilitative or compensatory methods.

METHODS

Patient Needs Assessment

Visual impairments, significant ataxia of the head and upper extremities, weakness, fatigue, paralysis, contracture/non-use of upper extremities, and dysarthric speech were identified as the major symptoms hindering participation in activities.

Computer Equipment Identified

Large screen display, voice output, enlarged keyboards, single switch scanning, keyguards, and communication board potential were identified as a feasible range of commercial computer adaptions. The primary software need was word processing, in lieu of non-functional handwriting. The following equipment was purchased: Apple IIe with Color Monitor (duo-disk drive, 128K, 80-column), Imagewriter II, Unicorn Expanded Keyboard (Unicorn Engr.), Adaptive Firmware Card (Adaptive Peripherals), a Prentke-Romich keyguard and several of their switches. Software included: Magic Slate (word processor with 20-,40-,80-column display from Sunburst Communications), Print Shop (Broderbund Software) and Appleworks (Apple Corp.). The total capital expense in 1986 was approximately $3,650.

Program Start-Up

Occupational Therapy evaluations were conducted as usual, but clients with an interest in computers, those with hand coordination problems, and those with significant disability were informed of this new service.

Adapted computer access was integrated into an individual's O.T. treatment plan, as appropriate:
Computer Orientation: Client/family shown how computer use could benefit client; demonstration only.
Computer Evaluation: One to four one-hour sessions resulting in recommendations for a system the client could operate, with training.

Computer Training: Two to ten sessions for gaining proficiency with the recommended equipment and software. Changes in recommendations may be made based on performance.
Treatment Activity: Any number of sessions, using the computer within other identified goals of the occupational therapy plan. Examples: improving coordination (accuracy and speed of touching target keys); improving range of motion and muscle endurance through creative switch placement with the engagement of the software as meaningful activity).

RESULTS

Adapted computer services were provided to 30% (25/83) of MS referrals to O.T. from May 1 to December 31, 1987. These 25 clients received a total of 59 O.T. sessions involving computer use. Ages ranged from 24 to 59 years, with a mean of 38 years. Length of diagnosis ranged from 1 to 29 years, with a mean of 8.5 years.

The Expanded Disability Status Scale (EDSS) [2] describes functional status in MS and ranges from 0 (normal neurologic exam) to 9.5 (totally helpless bed patient unable to communicate or swallow effectively). The mean EDSS rating of clients was 7.0, with a mode of 9.0, indicating the typical client to rely on a wheelchair, have significant neurologic dysfunction, and depend on others for some of their self-care. In fact, 36% were dependent on others for all needs; 60% were non-ambulatory.

Computer use was included in an individual's O.T. plan for the following reasons (multiple reasons occurred):

Option for meaningful activity	16	(64%)
Written communication	13	(52%)
Employment or school issues	9	(36%)
Improve hand/arm function	8	(32%)
Pre-environmental control +/or communication board use	5	(20%)

Symptom configurations of MS clients who received adapted computer services:

Upper extremity (UE) ataxia	12
UE ataxia, with nystagmus	4
No limb movement and visual deficit	3
Visual deficits only	3
UE spasticity	2
Impaired hand sensation only	1
TOTAL CLIENTS	25

DISCUSSION

More clients than had been anticipated were appropriate for computer services (30% compared to 20%). As anticipated, the majority of MS clients were significantly disabled and had very limited options for meaningful activities. Follow-through on recommendations is under assessment. Local clients were more readily served than those who could not return. Funding and technical support at home, common obstacles in the U.S., were minimized by allowing client-use of the O.T. computer after training. This improved follow-through and motivation.

Computer use was not appropriate if the caregivers or client "feared" technology. Another difficulty was motivating the severely disabled client, after years of dependency, to find applications for the computer.

The service was easily integrated into an existing O.T. program and start-up costs were nominal. Adults responded favorably and seemed to associate computer use with self-worth. Adapted computer use as a therapeutic activity meets the goal of occupational therapy practice, which assists individuals in the return to productive activity through rehabilitation and/or adaption of the environment.

CONCLUSIONS

Commercial computer adaptions can accommodate the ataxia and visual deficits of MS, and were in fact, a primary O.T. intervention in the face of inadequate conventional rehabilitative methods. Adapted computer services, which readily fit with the goals of Occupational Therapy, could be made more widely available through existing Occupational Therapy departments.

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USING COMPUTERS WITH THE PROFOUNDLY RETARDED

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INTRODUCTION

A research project using microcomputers and special switch controlled devices as part of the programming for a group of 12 multiply handicapped adults recently placed in a group home suggests that computers can be valuable in teaching some important skills but their usefulness is limited by the lack of suitable software. All of the group have some degree of physical handicap and estimated mental ages of less than 6 months. One unique aspect of the project is that there are two computers, one in their day program area and the second in the home where it is used in the evening and on weekends as part of both occupational therapy and planned recreation programming.

HARDWARE

These adults do not use the keyboard except with a special guard that allows them to hit a small number of selected keys such as the spacebar. Instead they use special devices including a variety of special switches that connect through an input box to the pushbutton inputs on the Apple. They also use the Touch Window from Personal Touch and the Power Pad from Dunamis. The Echo speech synthesizer has been used for voice output and with the correct phonetic spelling, they have all been able to recognize their name when spoken by the computer.

SKILLS TAUGHT

The first step has to be cause and effect - that pushing a switch or surface produces a change in what the computer does. Most of the group had used switches with battery operated toys but often got bored because there was no variability in what happened when they pressed the switch. The computer can provide a variety of visual and/or auditory output which can be tailored to the individual.

The next step is the concept of choices. Not only can they produce a change in their environment but they have some choice as to what that change will be. Not only is this important in facilitating environmental interaction needed for learning and a better quality of life but is an important first step in developing communication skills.

Throughout their program, the development of on-task and attentional skills is important. Initially this has taken considerable experimentation to find reinforcers of interest to each individual (those preferring tactile input are still a problem). A more advanced skill developed by two residents is the ability to take turns.

SOFTWARE NEEDED

The most critical need is for authoring programs that would allow insertion of appropriate reinforcers for individual clients. For example, one could choose the number of different reinforcers that would occur when the switch was pressed and then insert the still or animated pictures and/or sounds and music for an individual into the program and then save the program for use with that person. Similar programs are needed for the Touch Window and Power Pad which can be divided into two or more areas.

Currently there are very few programs which involve a small number of choices such as two switch programs (there is hardware for up to four switches). For the touch surfaces there need to be programs that move from 2 to 3 to 4 to 6, etc. divisions of the surfaces. One of the problems in teaching the profoundly retarded is that they need very small steps in introducing new information or any factor which increases the difficulty of the task. The exciting thing is that they can learn when the steps are small enough.

Most of the programs require multiple presses of the switch to keep something happening. The first step for this group is learning the connection between what they are doing and what is happening is best done with a program where the reinforcer continues as long as the switch is pressed.

Simple games provide the added incentive of an activity with another person. Many types are needed such as competitive games where you either have to hold down your switch continuously, hit the switch the most times, or hit it closest in time to some type of alerting signal. Simple games where you must take turns are important, but at least initially what happens when you press the switch should not be complex nor should any one turn require multiple switch presses. Later, simple cooperative games such as those requiring simultaneous switch presses may be possible.

One stumbling block has been the difficulty and time required to produce graphics on the Apple. The computer with a voice synthesizer could be valuable in developing communication skills if the same pictures appeared on the computer screen and on their communication board that could be put under the Touch Window or on the Power Pad.

RESOURCES

To date, we have found three important sources of software useful with this population. The U.C.L.A./L.A.U.S.D. has developed a number of programs for either the Power Pad or switches. Although designed for children, some of the programs are suitable for use with adults. Two commercial firms have both some software as well as hardware that is useful - Don Johnson Developmental Equipment, Inc. and Laureate Learning Systems, Inc. The software from Psychological Software Services has proved too difficult at present for our clients with a slightly higher mental age. The author has also developed some simple programs where there was simply nothing suitable available.

SUMMARY

The profoundly retarded is a group which has tended to be ignored in the development of specialized software. However, they can greatly benefit from the small learning steps and multiple, non-judgmental repetitions possible with suitable computer software. After having seen the exciting changes that have occurred in the residents in the less than a year that this project has been running, the staff is constantly clamoring for more software. It is hoped that this paper will both encourage the development of new software and better dissemination of information on what has already been developed.

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PREPOSITIONS ET ORDINATEUR: LE CAS DES ENFANTS SOURDS EDUQUES EN GESTUEL

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INTRODUCTION

Cette recherche a pour lieu d'origine le département de linguistique à l'UQAM-MTL. Son objectif premier est d'aider des enfants sourds, éduqués en gestuel, à mieux maîtriser l'utilisation des prépositions.

En obtenant la collaboration d'orthophonistes de l'Institut Raymond-Dewar (centre de réadaptation en surdité), il a été possible d'interagir auprès d'enfants sourds, en utilisant l'ordinateur comme outil d'intervention.

METHODES

Sujets

Les enfants sont 7 enfants sourds de la même classe qui utilisent un mode de communication gestuel, ils sont présentement suivis en orthophonie par madame Nicole Groulx. Ils sont âgés de 10 à 12 ans, ils proviennent de milieux francophones et on fait l'apprentissage de l'écrit. Ils fonctionnent en ce moment avec un programme de français 3^{e} année, à l'école Gadbois-Mtl.

Matériel

Le matériel d'intervention se compose d'un didacticiel conçu pour travailler 10 prépositions, les 10 plus fréquentes en français au Québec. Ce didacticiel comprend 4 niveaux avec 2 ou 3 exercices chacun. Il est accompagné d'un test pré-intervention (pré-test) et suivi d'une épreuve post-intervention (post-test). Les pré et post-test ont été exécutés par près de 300 enfants du secteur régulier de 2^{e}, 4^{e} et 6^{e} année. Ce pré-test nous donne une mesure de la maîtrise des prépositions par l'enfant. Quant au post-test, il permet d'évaluer les progrès de l'élève après qu'il ait travaillé avec le didacticiel.

Le didacticiel conçu à l'aide du langage-auteur Scénario, fonctionne sur un ordinateur IBM ou IBM compatible ou encore sur un ordinateur MAX-COMTERM.

Procédure

C'est l'orthophoniste qui a la responsabilité des entrevues avec les enfants. Elle les voit en individuel et peut créer le climat nécessaire au succès de l'intervention. Madame Groulx connaît bien les enfants et peut lors du déroulement de l'intervention, donner à l'élève les commentaires adaptés à la situation vécue enfant-ordinateur. L'expérimentation est d'une durée approximative de 10 semaines.

RESULTATS

Les résultats seront disponibles vers la fin de l'année scolaire juin 1988. Les enfants ont présentement terminé les exercices sur le didacticiel. Il reste la passation du post-test et l'analyse des données.

L'intérêt des sept enfants sourds pour l'ordinateur semble indéniable. Cet outil s'avère un bon moyen d'intervention pour des éléments du langage (les prépositions) qui posent des problèmes chez l'enfant sourd lors de ses communications orales et écrites.

DISCUSSION

Ces enfants utilisent un mode de communication gestuel et les prépositions, entre autres, sont des éléments problématiques dans leur communication. Ces difficultés sont apparentes aussi bien au niveau du codage du message (rédaction de textes) qu'au niveau de son décodage (lecture de textes). Ces observations ont fait l'objet de publications scientifiques (1), (2), (3). La communication gestuelle est un langage en soi et l'apprentissage du français peut être considéré comme l'apprentissage d'une langue seconde. C'est pourquoi, l'ordinateur apparaît comme un outil supplémentaire d'intervention et qui de plus, est agréable à l'enfant sourd pour lequel le français n'est pas toujours la matière la plus facile. Et ce français, nous le retrouvons partout...

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SCREEN READER
AN AUDIO ACCESS SYSTEM

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ABSTRACT

Screen Reader (TM) is an audio access system used by blind or visually impaired individuals. It enables them to access application programs, including text mode and window applications. It consists of an eighteen-key keypad, a program diskette with documentation, available on audio cassette tapes, online, Braille or printed format. Screen Reader attaches to the IBM Personal System/2 (R) pointing device connector, is PC DOS version 3.3 compatible and requires an external speech synthesizer for speech output.

INTRODUCTION

Screen Reader enables the blind or visually impaired user to perform the same computer functions as their sighted peers and to increase their competitiveness and productivity. Four years of use, plus test and evaluation information by blind and visually impaired users was incorporated in the Screen Reader design.

The Screen Reader option attaches to the IBM Personal System/2 and uses an external speech synthesizer which "Reads" system display information to the user.

Screen Reader can be used with the Personal System/2 as a stand-alone computer, a terminal or in a network. It runs concurrently with most application programs, enabling the operator to hear complete screens, lines, words, or characters. Software profiles tailored for specific applications, such as database managers, spreadsheets, word processors and other productivity tools, are included in the program. Screen Reader supports text mode window applications.

HARDWARE

The Screen Reader hardware consists of an 18-key programmable keypad attached to the IBM Personal System/2 via the pointing device port. A text-to-speech synthesizer attaches to the Personal System/2 via the communications asynchronous port. No additional attachment cards or ports are required. Six text-to-speech synthesizers have been tested for compatibility and are available commercially.

The keypad separates the Screen Reader commands from application related commands. It also enables the user to control the speech volume and speed, and whether the screen will be read by character, word, line, sentence, paragraph, full or partial screen. The keypad font is larger than that of other IBM keyboards to assist visually impaired users. In addition, to assist in finger orientation, two home position identifiers are available.

SOFTWARE

The Screen Reader software runs under PC DOS version 3.3. The operator loads PC DOS in the normal manner; Screen Reader software is then loaded. The selected application software is loaded and accessed via the computer keyboard.

The programming language Profile Application Language (PAL), allows users to customize Screen Reader functions and keyboard definitions for specific applications. It also provides for tailoring the keypad to a user's applications.

A PAL compiler takes as input a standard ASCII text file, and Screen Reader compiles this source code to a hypothetical machine object output.

The memory resident portion of Screen Reader consists of a PAL object interpreter as well as device interfaces for the keypad and synthesizer.

Screen Reader runtime modules are interrupt driven; the keypad and synthesizer are character interrupting devices. In addition, the main portion of the PAL interpreter is also interrupt driven from the system timer interrupt. The PAL interpreter performs a pseudo task switch when necessary from the currently executing user application of Screen Reader and back.

Screen Reader provides an "autospeak" and windowing capability. Autospeak enables the user to monitor up to 20 display screen areas and speak aloud changes as they occur. These changes could have gone undetected without this autospeak function. The windowing facility allows a user to create a window or box around a block or column of text and hear the information for that specific area.

DOCUMENTATION

The documentation is provided in various formats. Audio cassette tapes provide user installation instructions. An online User's Guide designed to work with Screen Reader describes the product. A table of contents, index and a glossary are available online. A tutorial provided online, is also available on audio cassette. This gives instructions on Screen Reader's installation and use. For users who prefer Braille, a User's Guide is available in that format.

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ACCESSIBILITY OF GRAPHICALLY BASED USER INTERFACE COMPUTER SYSTEMS FOR INDIVIDUALS WITH VISUAL IMPAIRMENTS

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OVERVIEW OF THE PROBLEM

Graphically based user interfaces are becoming the standard user interface for computers. This is evident in the move over the last several years in the microcomputer world toward the Windows/Presentation Manager and the Macintosh user interfaces, as well as the popularity of XWindows and NEWS in the mainframe and mini-computer world. In addition, the recently developed Display Postscript makes sophisticated graphics available for the display. The reason for this move toward a graphical user interface is because it provides a better interface medium for the majority (i.e. sighted) of people.

Graphical user interfaces also help individuals with some visual impairments use computers. They help in that they provide easy software means to enlarge or magnify the screen image for individuals with low vision. The newer operating systems also prevent programs from dealing directly with the video hardware, so adaptive programs designed to give the individual with visual impairments have greater success maintaining a "picture" of the screen.

However, these systems currently hinder the more severely visually impaired individual from using the computer in at least two ways.

First, some of these systems have architectures such that it is not technically feasible for the adaptive programs to gain sufficient access to what is displayed on the screen. There is also currently no way to sufficiently intercept the calls from the application program to the operating system to monitor and reconstruct what is being placed on the screen.

The second and more difficult problem is common to all graphically based user interfaces. Graphical user interfaces (output, input, and control) are designed for the user who has had sight since birth. Individuals who have been blind from birth have a difficult time with the output of these systems. They have difficulty reconstructing a "picture" of the screen because they have different perceptions of the world around them, and often have different conceptualization skills. In addition, the blind individuals are unable to effectively use the input mechanisms, such as the mouse, which rely heavily on continuous visual feedback for effective use. Lastly, the control strategies of these graphical user interfaces depend on the intuitiveness of presenting visual real-life analogies for controlling the computer which are not the same for individuals with visual impairments.

DISCUSSION

The accessibility of graphically based user interface systems can be broken down into two main areas: 1) the technical aspect of providing an operating system which is conducive to allowing adaptive programs/devices to provide the required user interface for individuals with visual impairments (i.e. making it technically easy to connect special alternate input and output devices), and 2) the human factors aspect of the adaptability of graphical user interfaces for sighted persons to an effective user interface for individuals with visual impairments.

The technical features of an accessible operating system

These graphically based user interface systems have bit-mapped screens, and once anything is written on the screen, it is currently only available in bit mapped form. It is therefore important to have the system be able to allow the adaptive programs, for individuals with visual impairments, to intercept the calls to the operating system which draw on the screen so that the adaptive program can identify the words, letters, symbols, etc. as they are being drawn rather than having to deal with only the bit-mapped screen. However, many of the current graphically based user interface operating systems do not allow the application programs and even the special adaptive screen access programs to "know" at all times what is on the screen, or what was recently placed on the screen. Even if they provide access to what is being written on the screen, they sometimes provide too low level of information to the adaptive program, by providing access to only low level drawing commands. For example, the operating system may allow the adaptive program to intercept calls to the operating system to write a dot, draw lines, or bit-blits, but do not let access to the calls to the operating system to draw a box (which is made up of four calls to the line drawing routine) or to draw an irregular polygon and fill it with a certain bit pattern (which is made up of many calls to the line drawing routine, and many bit-blits), or draw a window (which is made up of many functional and visual sub components).

Adaptability of the graphical user interface

The adaptability of graphically based user interfaces to the individual with visual impairments is three fold: output, input and control.

Output: First there are the cognitive and perceptual barriers that exist when trying to get a visual "picture" of a screen (which is normally achieved by processing visual channel) via the non-visual channel (e.g. tactile, auditory, etc.) and with the perceptual skills of the individual.

It is already known that congenitally blind individuals often have different conceptualization skills and do not perceive the world like the sighted individual. They often cannot easily identify objects from different visual perspectives. For instance, even if the blind individual has a tactile outline of a coffee cup viewed from eye level, the congenitally blind individual will not immediately, or ever, recognize it as a cup. But if you give the individual a tactile outline of a coffee cup viewing it from above, it is easily recognizable. This is because they "see" a cup from above by using their fingers, and rarely try to identify it by feeling it from the side (Ewers 1987).

The congenitally blind individual also has difficulty with visual abstractions of an object. The sighted individual has seen many different trash cans in their life, and is able to somehow sense a visual abstraction of the "generic" trash can. They also have the ability to make the abstraction of this generic trash can into a simple line drawing. However, many blind individuals, even if given a tactile equivalent to a line drawing of a trash can (again as viewed from the side) are unable to easily identify it (Ewers 1987).

Input: The second problem is adapting the input mechanism of the graphical user interface to allow efficient use of these input devices. We normally do not think that the visually impaired user will have problems using the input mechanism of a computer. However, it is quite difficult to separate the user input mechanism from the user output mechanism of the graphic based computers. For example, effective use of the mouse is not just simply a matter of fine motor control of the hand, but includes good "eye-hand" coordination. For the individual who has low enough vision that they require the screen to be magnified eight times (so they can only see one sixty-fourth of the screen at a time), using the mouse can be difficult. For the blind person, it is impossible. But this is only a taste of things to come. There is currently being developed an input mechanism that uses a sensing glove. The computer system is based on a three dimensional display, and instead of a mouse pointer, uses a picture of a hand, controlled by the glove, to serve as the input to the computer system. The user would put on the glove and use their hand to control the hand image on the display in order to manipulate the objects on the screen, or to operate the user interface.

Controls: The third problem is the control aspect of the user interface. Since the user interface is very visual, the control aspects of the user interface will try to simulate real-life situations. We see this already with dragging items into a trash can, or pushing radio buttons. However, the individual with visual impairments has a different set of control strategies and perceptions. As the graphical user interface becomes more sophisticated, providing almost real-life three dimensional displays, this problem may become worse.

The concept of overlapping windows, and bringing a window to the top to make it the currently active window is intuitive for the sighted user. But this control mechanism for selecting the active program or aspect of a program may be difficult for the individual who is blind from birth and who also cannot read braille (i.e. has never had to "shuffle papers") since they may have never developed the concept of having to bring something to the top, visually, to "see" it or work with it.

In addition, since currently most input controls require physical control, and since the visually impaired user cannot rely on visual feedback, the controls for the visually impaired user should incorporate some tactile feedback into the input device. An example would be a force joystick. The visually impaired user could move the cursor or mouse pointer around the screen with the joystick, but the force required to keep the joystick in the current position could be related to the current item under the pointer or the visual items being crossed.

CONCLUSION

The new graphically based user interfaces have provided easier interfaces for the sighted individual. With increased speed and resolution of graphical displays systems, we will soon have more ability to customize the visual interface for the sighted individual. However, we must be very cautious that these new graphical systems and the computers that use them, are not designed in such a way that they cannot be made accessible to the blind individual. These systems should be designed to allow different user interfaces without requiring the application program to adapt. Thus there can be user interfaces to take advantage of the sophisticated graphics of the computer, and others for individuals with visual impairments.

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A PROGRAMMABLE, RS-232 CONTROLLED, INFRARED CONTROLLER

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ABSTRACT

For some physically disabled individuals, operation of a keypad, whether computer keyboard or pocket calculator, can be a difficult and sometimes impossible task. A voice controlled computer-based work station integrating telephone management, environmental control, software control, and infrared control was developed at the Hugh MacMillan Medical Centre, (HMMC), for persons with high level quadriplegia. This paper describes the development of an interface unit between the workstation computer and a modified hand-held programmable infrared controller.

INTRODUCTION

The infrared controller gives remote access to home entertainment devices by transmitting encoded invisible light signals, in the infrared wavelength, from a hand-held transmitter to the entertainment device. This code can be transmitted by several different methods and code formats, with each manufacturer using whatever method and format is most convenient for them. The transmission code and format must be compatible with the infrared receiver for the transmitted data to have meaningful results or any results at all. Because of the variety of infrared transmission methods and codes, designing an interface to allow handsfree operation of all infrared controllers would require a number of custom adapters to be constructed. Each adapter would be dependent on the model of appliance the user selected, and therefore a more generalized solution was required.

METHOD

For the purposes of the project a commercially available General Electric, Control Central, was chosen. This is a hand-held infrared controller similar to any TV or VCR remote control. The difference is that the Control Central is a trainable device having the ability to "learn" other device's codes. The "learning" of new codes, not already in the Control Central's memory, is performed by placing together the infrared transmitting ends of both, the Control Central and the infrared transmitter to be learned. Matching keys are then depressed on both controllers. The complete procedure is prompted from the Control Central's alpha-numeric liquid crystal display and requires, at most, three passes through the key sequence to learn the new code for each key.

A new infrared code can be learned for each key on the Control Central keypad. In addition to this however the keypad may also be switched through four banks, called TV, VCR, CABLE and AUX, by the SOURCE key to give up to a total of 130 different codes that can be learned and transmitted by the Control Central. Note that although the keys are labeled POWER, CHANNEL UP etc., the function of a code learned under that specific key does not have to relate to its label. This ability to store a large number of codes from many different transmitters makes it possible to now have one remote control that can operate all infrared controlled devices in a home.

The interface unit, mounted on the back of the Control Central, see Figure 1, is connected through a miniature 14 pin connector. This allows the Control Central to be disconnected from the interface unit and used in its original form as a hand held infrared controller. The addition of a diode to the Control Central +Vcc line makes it possible for power to be supplied through the 6 volt interface unit power supply. In this way the Control Central's own batteries are not drained while plugged into the interface unit.

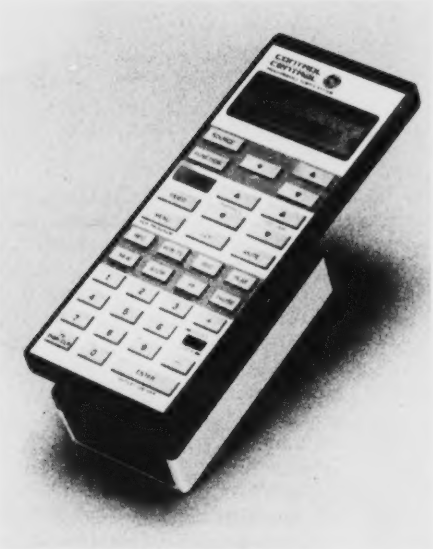

Figure 1: Programmable Infrared Transmitter and Interface Unit

Voice initiated commands, from the workstation computer, are transmitted through the computer RS232 serial port via cable to the interface mounted on the back of infrared controller. A single chip microprocessor (MC68705R3) in the interface receives, interprets and implements these commands through the infrared controller. The microprocessor is required to separate commands meant for the infrared controller from other serial commands sent from the workstation. Since the infrared controller is organized in blocks of commands (TV, VCR, cable, auxiliary) it is sometimes necessary to sequentially punch several keys to finally implement the desired function. The microprocessor is able to store the current state of the infrared controller and "press" the appropriate keys to select the next desired function.

The commands sent to the interface by the workstation are relayed to the Control Central by the MC68705R3 controlling electronic switches wired in parallel to the Control Central's keypad. These switches are turned on and off by the MC68705R3 in a way that simulates keys being pressed. Before a command is implemented the interface will switch the Control Central to TV mode. This is the starting reference point for the MC68705R3 and is detected by a signal on the Control Central's display characteristic of it being in TV mode. It is necessary to do this since the Control Central will remain in whichever one of the four modes TV, VCR, CABLE or AUX, it was last used in and since the controller can be removed and used separately it would be possible for the microcomputer to expect the Control Central to be in one mode when it was actually in another.

CONCLUSIONS

Although in its current form the interface only interprets ASCII text strings from the RS-232 Port, the capability is there with minimal additional hardware to have the MC68705R3 read switch inputs and through a menu selection technique give a person single or multiple switch access to entertainment devices through the Control Central infrared controller.

Alternatives to the General Electric Control Central programmable infrared controller have, since the end of the project, become commercially available through Radio Shack and Magnavox.

ACKNOWLEDGMENT

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MODULAR SINGLE-SWITCH WORDPROCESSOR AND CALCULATOR FOR CLASSROOM APPLICATIONS

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INTRODUCTION

Investigators at the University of Tennessee at Chattanooga (UTC) have developed a single-switch accessed wordprocessor and calculator for disabled users in an educational environment. This system (SET-1), the first module in a series of compatible systems being developed at UTC, offers the user a choice of modes of operation including: writing, calculating and communicating. The user also can select the scanning rate and method.

The SET-1 system differs from several other computer access systems [1,2] in three major ways. First, SET-1 provides a very user-friendly interface. Second, the system provides features including a four function calculator, and printout of coursework answer sheets and compositions, and can be programmed easily to provide specialized screens and functions. Third, SET-1 is designed to be compatible with other modules to facilitate environmental control, mobility control, and guidance via an expert system.

METHODS

The considerations [3] involved in selecting the design paramaters for SET-1 included: the type of microcomputer - availability of switches, control devices expansion peripherals; the type of input - direct selection, scanned, voice, etc.; the type of switch simulation system - either hardware/software modifications to enable the use standard software [4], or a specialized software environment with keyboard interface hardware circuitry to enable the use of commercially-available switches; and the language for writing the programs.

The IBM PC microcomputer was selected because of its wide usage in education and the wide availability of interface devices. The single-switch scanned selection method was adopted because it represents one of a few modes of computer access for the severely physically handicapped, while others could use the system in a two-switch mode or override the switch by direct selection mode if necessary. Also, several individuals were identified who were in need of such a system.

Among the "high level" languages, the speed of C is very close to that of assembly language and is very efficient for interfacing with the system's ROM and hardware devices. Finally, C is one of the most efficient languages for developing "in-line" assembled expert systems. Since SET-1 and other modules were planned to be integrated with an expert system, C was selected for this application.

Discussions with care providers and clinicians brought out the paramount importance of user-friendliness. The available keyboard emulators, which operate with standard software [4], provide a linear array of alphanumeric characters at the bottom of the screen, and require a significant learning effort by the user. By contrast, SET-1 was intended to be capable of altering the configuration of the scanning section of the screen, including size, shape, location and color based upon the application mode desired. This could be accomplished only through the design of specialized software for SET-1.

RESULTS

The current version of SET-1 has four basic modes of operation accessible from the "Main Screen":

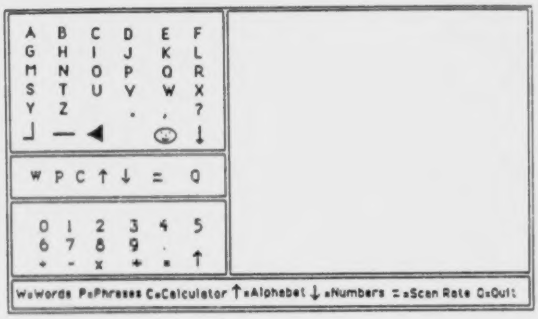

Figure 1: SET-1 Main Screen

The Main Screen provides an interface to the entire module (Figure 1). The upper section of the selection area provides the alphabetic characters and control symbols for wordprocessing. The master selection menu, in the center, provides access to the various modes of operation defined at the bottom of the screen. The lower section provides numerical characters and arithmetic symbols for use in the wordprocessing or calculator mode. The right portion of the screen is the work area for wordprocessing.

The Writing Mode is accessed by selecting 'W' from the Main Screen. This mode provides basic wordprocessing capabilities including the ability to print, or send text to a voice synthetizer.

The Calculator Mode utilizes the upper section of the selction area (previously occupied by the alphabetic characters) as the calculator workspace for arithmetical operations.

The Word Selector Mode provides a more rapid means of constructing sentences and communication. The screen for this mode is programmable to include any combination of words and symbols.

The Common Phrases Mode utilizes the entire screen for a programmable array of commonly used phrases. This mode also serves as a gateway for environmental control capabilities.

In addition, there is a scanning rate adjustment screen which is accessible from the main screen as well as from the writing, calculator or words mode.

DISCUSSION

Initial development of the system started with the referral to UTC of a severely physically disabled child from the Siskin Foundation. Discussion with this child's parents, therapists and teachers led to some of the basic design considerations for the user interface and the operational modes. In addition to tests with this child, detailed testing for each mode was conducted by both disabled as well as non-disabled students. The system was tested and proven to operate properly in several IBM PC compatible microcomputers.

Planned enhancements to the SET-1 software include: automatic adjustment of scanning rates; wider selection of scanning methods; enhancements of the screen editor; and the ability to save and retrieve data using disk files.

The SET-1 system can be transported readily to the IBM PS/2 with a simple redesign of the switch interface to the microcomputer's parallel I/O port. Access to standard software also can be provided through "ram-residence" or through the use of a multitasking environment such as Windows or the OS/2.

CONCLUSIONS

SET-1 provides a programmable and expandable user-friendly environment for wordprocessing, calculating and communicating via single-switch access to an IBM PC microcomputer. This modular system, developed in C, can be integrated readily with switch- actuated controls for environment and mobility currently under development.

ACKNOWLEDGEMENTS

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THE APPLICATION OF A POCKET COMPUTER AS A KEYBOARD EMULATOR FOR INDIVIDUALS WITH DEGENERATIVE MUSCULAR CONDITIONS

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OVERVIEW

A commercially available pocket-sized computer has been adapted to emulate the keyboards of various popular personal computers. The features of the pocket computer make it ideal as a computer interface for individuals who have reduced strength and range of motion. In addition, a single pocket computer can contain emulation programs for two or more different target computers, allowing an individual to use a consistent interface in, for example, home and work settings.

BACKGROUND

Individuals with degenerative muscular conditions, such as muscular dystrophy, will often experience difficulties using standard computer keyboards. As upper extremity strength and range of motion decline, typing proficiency also declines in the form of impaired speed and endurance.

Solutions to address computer use for these individuals have typically involved either direct accessing methods such as small keyboards, or indirect accessing methods such as scanning and Morse code. Clinical work at Bloorview Childrens Hospital with adolescents having Duchenne muscular dystrophy has included both of these approaches, with varying results.

The adroit approach seemed to be to recommend an indirect accessing method, Morse code. Good fine motor control leant itself well to this, and the physical effort required can be made very small. The typing speeds were potentially as high or higher than those for a one-digit typist. In addition, physical function to do Morse code is likely to be retained throughout most of the course of the condition. Early intervention with Morse code, when the user was first beginning to struggle with a standard keyboard, was seen as a solution that would serve the user well.
For some users this approach has been successful, but many others have struggled with the switches and the codes until finally rejecting the method and sometimes even the computer. In some cases the user would go back to laboriously using the standard keyboard.

In a condition such as muscular dystrophy, a variety of emotional responses are evoked by the lessening of function. These can include anger, denial, and depression. The rejection of an indirect computer accessing method, such as Morse code, is not surprising for many individuals experiencing these emotions. The user must give up forever the "normal" keyboard, and accept a specialized "disabled" method. There is a considerable amount of effort required to memorize the codes, and the user may resent this burden. They may deny that they really need such a method, and doggedly persevere with the standard keyboard.

There is little doubt that, for an individual who can learn to use Morse code, this method will serve them well through the course of their condition. But for those who cannot, or will not, a direct accessing alternative may be considered.

The most widely distributed miniature keyboard for direct accessing is the TASH mini keyboard, which is a matrix of 64 small light-touch membrane keys. An interface is required, such as an Adaptive Firmware Card (Apple II), or a PCAID (IBM PC) to scan the mini keyboard and provide emulation to the target computer.

Staff at Bloorview Childrens Hospital conceived the idea of a commercially available pocket computer serving as a miniature keyboard, and offering some advantages over other available devices.

DESCRIPTION OF THE MINIATURE KEYBOARD

The pocket computer chosen for this application is a Sharp PC-1360, a small (about the size of a cheque-book) and light weight unit with a QWERTY style key arrangement and a numeric keypad. The small keys are raised above the unit surface for tactile feedback, and require in the order of only 30 grams to activate. There is also a four line by twenty-four column LCD screen, and a built-in speaker.

A bi-directional port allows connection to external devices. Technical information from the manufacturer is available describing this port, as well as the machine language instructions used in its proprietary microprocessor. Machine language programming of the device is necessary to achieve adequate speed for keyboard emulation.

The emulation program is loaded into the non-volatile memory of the device. A cable connects the output port to the keyboard port of the target computer, and also connects power to the pocket computer, saving its own batteries. The pocket computer can be set on a table or a tray, or it can be mounted on a flexible arm.

Pressing a key of the pocket computer causes the appropriate output signals to be sent to the target computer, emulating that keystroke on the regular keyboard. The user is provided with both auditory and visual feedback. A 'click' is produced by the pocket computer's speaker, and the screen of the pocket computer displays up to the last twenty-one characters typed. One finger operation is supported, and keystrokes requiring simultaneous key closures use latching functions, the status of which are displayed on the screen.

Currently, target computers supported are the IBM PC and compatibles through the keyboard connector, and the Apple IIe and IIgs through the Adaptive Firmware Card. Work is underway to emulate the Apple Desktop Bus, which would then allow connection directly to the Apple IIgs, the Macintosh SE, and the Macintosh II. Other computers which have detached keyboards could be emulated as well.

The pocket computer's memory can contain two or more emulation programs at a time, allowing a user to use two or more different computers in different locations. Only the proper connection cable for each target computer is required.

ADVANTAGES

To date, the user acceptance of a direct access device for an individual with a degenerative muscular condition has been good. Subjective comments received from users of the pocket computer keyboard have been encouraging.

The appearance of the unit, being a commercial product and resembling a sophisticated calculator, has been well-received by users. It presents like a "normal" device which would fit into any office environment, rather than as a specialized rehabilitation device.

The on-screen feedback to the user is in very close proximity to the pocket computer's keyboard, thus allowing the user to easily confirm immediate text entry without having to look at the computer monitor. This saves time and reduces fatigue since the user can reduce the amount of head movement that would be required in glancing from the keyboard to the target computer's screen.

The ability to use the same consistent interface with more than one computer can have advantages for users dealing with different computers at home, school, or work. The small size of the pocket computer allows it to be easily carried from location to location.

The cost of the pocket computer compares favorably with other commercially available miniature keyboards. Furthermore, as most target computers will not require specialized emulating interfaces, costs for the pocket computer are considerably lower than for other adaptive solutions.

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ELECTRONIC KEYLOCKING FOR THE APPLE IIe

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INTRODUCTION

As computers begin to dominate the work place it is apparent that everyone needs to be able to access them. Most computers require some multi-key commands (i.e. SHIFT & ANOTHER KEY or CONTROL & ANOTHER KEY). For some disabled individuals these multi-key commands are difficult or even impossible to execute on a standard keyboard. To overcome this accessing problem, keylocks were developed. They help the user by maintaining the closure of the modifier key (i.e. SHIFT OR CONTROL) which frees the user's hand to select the next key.

PROBLEM

Most, if not all, of the keylocks currently available are mechanical in operation. That is, they physically hold the modifier key down or closed. These keylocks have been shown to work. However, there are still some problems associated with them. Mechanical keylocks must be mounted alongside the keyboard in order to operate correctly. This in itself introduces two problems. Firstly; with the keylock mounted alongside the keyboard and covering all or part of the modifier keys, the keyboard now becomes difficult to use for a person who normally would not use a keylock. Therefore, the computer loses some of its versatility. Secondly, the mounts for some of these keylocks have been found to be unreliable. They are often not strong enough to withstand the rough usage they are sometimes subjected to and, as a result, the keylock malfunctions and requires repair. Another small problem with mechanical keylocks is with their basic operation. These keylocks require the user to disable them as well as enabling them. Therefore the user is actually making three keystrokes to get a two keystroke input. A problem regarding mechanical keylocks unique to the Apple IIe and IIc computers is that there are few, if any, keylocks available for the open-apple and close-apple keys on the keyboard. This may be due to the location of the keys and the inadequate space for the mounting of a keylock.

SOLUTION

In an attempt to overcome these problems with mechanical keylocks and still maintain the ability to function with all software, an electronic hardware design approach was taken. The electronic keylock was designed around an Apple IIe computer. It electronically locks the modifier key closed after the key has been activated from the keyboard. The modifier key can, therefore, be physically released while the electronic keylock maintains the connection. The electronic keylock will release the connection a short time after detecting a regular key (any number, letter or punctuation) closure. This approach means that nothing has to be mounted on or near the keyboard so the computer remains functional for all keyboard users. Since the keylock is activated through the regular keyboard there are no problems with the unreliable or weak mounts found with some mechanical keylocks.

Because this keylock auto-releases the locked key, it takes only two keystrokes to perform a shift or control function as opposed to three keystrokes for a mechanical lock. The electronic keylock also supports the locking of the open-apple and closed-apple keys. However, this introduced another problem which had to be resolved. When software requires input from a joystick or paddle control only, it is undesirable for the open-apple or closed-apple keys to lock. Since the keyboard is not being used, these locked keys would never be released. To get around this problem, a means of switching the locking function of the open-apple and closed-apple keys on and off is needed. On the current version of the Electronic Keylock the locking function of these keys is switched on and off with a mechanical switch mounted on the keylock box which is secured to the side of the Apple IIe computer. However, on future versions the locking function will be switched electronically by detecting two unique three key sequences from the Apple IIe keyboard. One key sequence will enable the locking and another sequence will disable the locking function.

DESCRIPTION

As mentioned above the present version of the electronic keylock is housed in a box (112 x 62 x 27 mm) and secured to the side of the Apple IIe. It has four status LED's indicating the current state of the four modifier keys (locked or unlocked). Two switches are mounted on the box for easy user access. One switch, as previously mentioned, controls whether or not the open-apple or closed apple keys will lock. The other will stop the keylock from auto-releasing the locked keys. This allows the user to input continuous shift or control functions. On future versions, it is planned to house the circuit totally inside the Apple IIe and eliminated the status indicator as well as the switches in order to reduce cost.

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THE TRACKBALL AS AN ALTERNATIVE INPUT DEVICE

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Alternative input devices for personal computers are becoming increasingly popular for persons with or without disabilities. One popular device for some programs is the mouse. Many programs (Microsoft Word®, Ventura Publisher®, most graphics programs, for example) include mouse capability, and other programs (WordPerfect®, Lotus 1-2-3®, dBase III®) have had mouse interface software written for them after release. Many higher level spinal cord injured persons, however, cannot use a mouse (due to lack of dexterity, range of motion, or spasm control) because they cannot effectively position, hold, and click the buttons. Attempts to replace the mouse with other hardware or software have been mentioned in the literature, with varying degrees of success (1,2). Many of those persons who are unable to control a mouse or use these other approaches may be able to use a trackball.

The trackball is similar to a mouse turned upside down, like that used in the video game "Missle Command", which moves a cursor on the screen to position "explosions". It looks like a mouse to the computer. Trackballs have been manufactured for the Apple II, Macintosh, and PC families, among others. For most of these computers, the trackball is in a separate housing which connects to the computer via a serial port; and mouse software converts the trackball signals to cursor movement on-screen.

A trackball installation for a user with cerebral palsy has been reported in the literature (3). Our task was to enable computer operation by a person with C5-C6 quadriplegia.

The trackball needs to be positioned at a location where the ball can be contacted by a body part able to move in a plane. Movements of any size are acceptable, and spasms usually will not affect the final outcome of most programs (screen effects of spasm are usually correctible). Several small movements can be made to position the trackball pointer anywhere on the screen; the mouse requires a fixed amount of movement area (or requires that the mouse be picked up). The trackball does not need to be grasped nor does it need to be held in position while buttons are depressed. The buttons on the trackball module can be activated by a typing aid, or even the side of the hand, where such control exists.

CASE STUDY

An 18 year-old patient with C5-C6 incomplete quadriplegia, with limited shoulder control, was evaluated for computer accessibility, with a goal of determining potential employment and recreational opportunities. Past employment history was limited, and except for a background and interest in art, no major skills or interests had been identified through vocational rehabilitation evaluation. Initial patient exposure to a computer with only a keyboard proved to be relatively nonproductive. Although this patient was able to manipulate a keyboard with a typing aid, he was discouraged by the slow speed and inability to smoothly manipulate graphics. The patient was unable to smoothly manipulate a mouse and was incapable of depressing the buttons while maintaining mouse position. When introduced to a trackball, the patient exhibited superior skills in "painting" and CAD programs. A secondary result was that other therapists working with the patient subsequently reported improved morale and increased compliance with therapy goals. The patient's demonstrated graphic and artistic activity with a trackball introduced the possibility of employment in computer aided design activities, and created an interest in working with the computer for creative entertainment as well.

SUMMARY

Evaluation of the trackball as a commercial alternative input device has shown that it can be valuable for some persons with upper extremity limitations. Further evaluation will be undertaken on trackballs from several vendors; factors to be considered include mouse emulations available, mechanical limitations to operation in non-horizontal mountings, and ability to externalize the buttons for switch adaptations.

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THE KEYBOARD AND MOUSE EMULATOR

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ABSTRACT

The Keyboard and Mouse Emulator (KB-Mouse) was developed that allows quadriplegics to operate the functions of a keyboard and a mouse for a personal computer, by using a small size digitizing tablet and the special mouth stick. This paper describes a principle and an evaluation of the KB-Mouse.

INTRODUCTION

Recently in Japan, many severely handicapped individuals have been interested in using a personal computer.
However, especially for quadriplegics, an input device becomes a big problem. In order to operate the keyboard, a long and heavy mouth stick is needed. And lock the shift key, the reconstruction of a keyboard becomes necessary. Also, a regular mouse can not be used for the quadriplegics.
Thus the KB-Mouse that emulates the functions of a keyboard and a mouse by utilizing a small size digitizing tablet, was developed.

DESIGN GOALS

1) To provide a device that can be used with a most popular MS-DOS personal computer (NEC 9800 series) in Japan.
2) To allow easy installation of hardware and software with no or a few changes.
3) To allow the use of many application software available on the market.
4) To fully emulate the functions of a keyboard and a mouse.

KB-Mouse

Hardware

Figure 1 shows a diagram of the KB-Mouse. A target system is the most popular MS-DOS personal computer (NEC 9800 series) in Japan.
A small size digitizing tablet is WACOM WT-460M. A special feature of this tablet is wireless. A sensor unit that was made up of a puff and sip pneumatic pressure switches, can be took the place of a regular mouse switches. At the tip of the mouth stick attached is a small size magnet. A connector of tablet is connected to RS-232C serial interface of a personal computer. A connector of a sensor unit is connected to the bus-mouse interface.

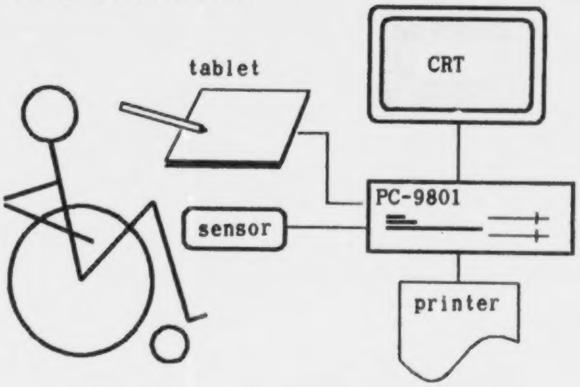

Figure 1. the diagram of KB-Mouse

Software

A device driver of software of MS-DOS was developed. This software is copied to an application software on the market and registered at a config.sys file.

Input Methods

When the KEYBOARD key of overlay is pointed with a pointing device, it becomes a keyboard mode. In this mode, a character can be input as on a regular keyboard. The MOUSE key being pointed, it becomes a mouse mode. In this

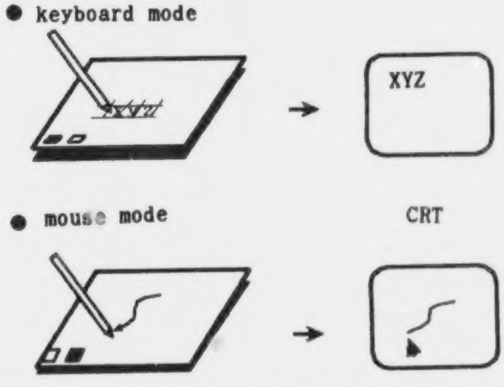

Figure 2. the input methods of KB-Mouse

mode, a locus of a tip of a pointing device can be input as the information of relative position such as a regular mouse. (see figure 2)

In a keyboard mode, there are many functions of shifting lock, non-auto repeat and a user definition (maximum 16 characters / key).

In a mouse mode, the quantity of a relative movement can be changed.

Figure 3 shows the examples of the pointing method.

Overlay

Figure 4 is an overlay that is attached on the surface of the tablet. On the overlay, alphanumeric keys, katakana keys for Japanese, function keys, printer control keys and KEYBOARD / MOUSE keys are printed.

RESULTS

The KB-Mouse is now being used by one cervical cord injured individual (C4). He is now 40 years old. Figure 5 shows a scene of using the KB-Mouse. He is utilizing it for Computer arts, Japanese word processing and accessing Communication Bulletin Board System (CBBS). Figure 6 show the examples of his art work.

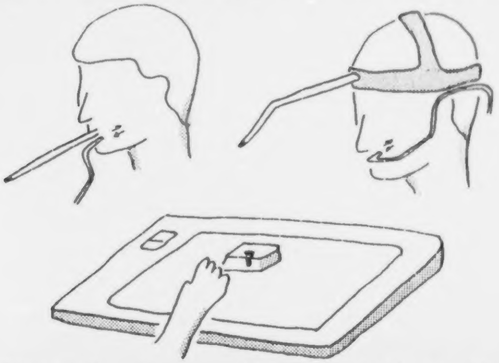

Figure 3. the examples of pointing method

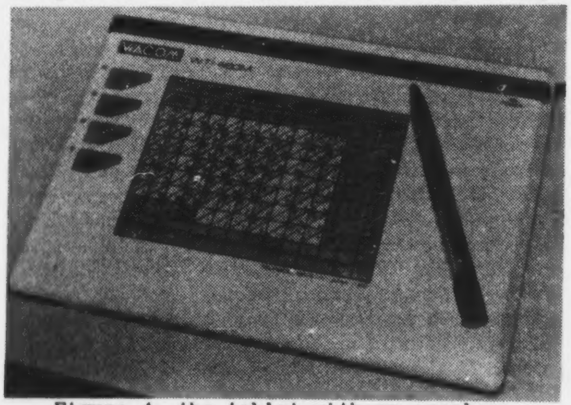

Figure 4. the tablet with an overlay

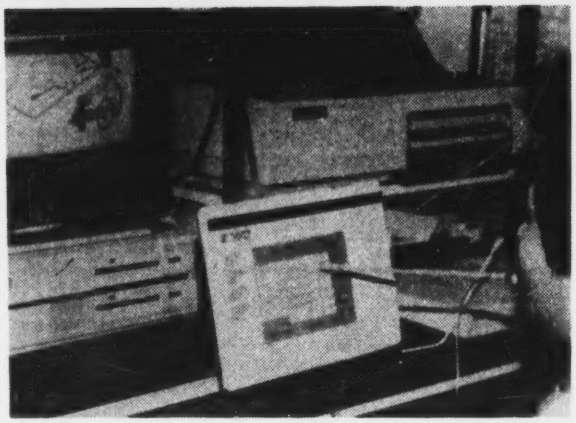

Figure 5. the scene of using the KB-Mouse

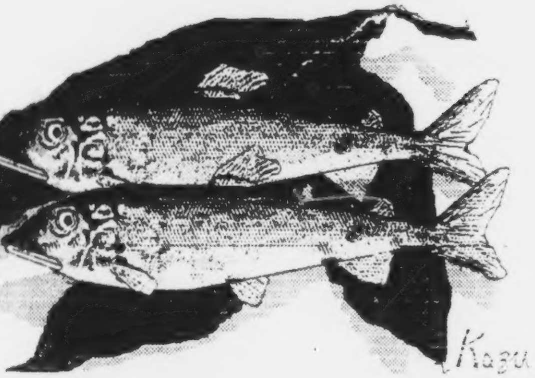

Figure 6. the example of art work

CONCLUSION

At present time, the KB-Mouse can be utilized to approximately 50 percent of the application software on the market. The reason is that the KB-Mouse cannot be utilized to the application software which is using the special input routines.

We are planning to develop the KB-Mouse with other system witch can be used with all of the application software on the market.

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APPLE TO IBM PC COMMUNICATION
AND APPLIANCE CONTROL SYSTEM(PLUS)

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ABSTRACT

This paper will interest those concerned with a PC based communication and appliance control system for verbal or non-verbal quadriplegics. The solution presented here achieves the intended goals. The goals were:

1. System cost less than $2,000.
2. Commercially available hardware.
3. Maintain compatibility with Northwestern University Program.
4. Features include:
    a. Text Editor anticipatory arrays
    b. Telephony
    c. Appliance controls
    d. Music composition
    e. Math support
    f. Game support
5. Voice recognition (additional $900)
6. Maintain usefulness as a home PC for other members of a household.
7. Ease of installing and use.

DISCUSSION

This project began as a need to provide a non-verbal quadriplegic with a system similar to the Northwestern (NUCDC) program. The donor system (provided by Telex Computer Products) was a PC compatible and therefore not able to accept the Apple based (NUCDC) program. The conversion was further complicated because the software made assumptions based upon Apple specific dependencies. Based on the above, the strategy best suited was a total redesign using the new architecture and the latest in software tools. However the external presentation was to remain closely compatible with the NUCDC. This desire for compatibility was to accommodate those who had previous familiarization with NUCDC. Additionally, this would provide an easier upgrade path for existing users desiring advanced features requiring replacement of obsolete hardware. The appliance controller module, for example, would control existing appliance modules used by the old system. It is recognized that functions provided by this new system ENABLE, can be installed singularly based on independent technologies. However, ENABLE is a conduit funneling all inputs through one input device as opposed to many input devices for each standalone device. The single ENABLE input may consist of a puff-sip, switch(es), or voice (microphone). The input is received by the computer, then routed to the proper software module and finally to the external device, for music composition, modem for phone dialing, math, text processing, and appliance control, etc.

INPUT MODULE

The main software input module accepts input from any of three devices:

1. Keyboard
2. The game port controller board
3. Voice recognition board

KEYBOARD INPUT

The keyboard input was originally for debugging the system. The intent of keyboard input was to simulate action of either one switch attached to a patient's eye brow, or a puff-sip or a multiple switch arrangement. As the design progressed it became apparent that use ofthe keyboard during the training process with therapist and quadriplegic substantially reduced the training time allowing more efficient use of the therapist's time. Additional speed is gained by the therapist using the keyboard since more combinations of input are readily available and shortcuts can be taken. Another benefit derived from the keyboard input path is compatibility with voice recognition devices. The system does not require a keyboard being present. In fact, ENABLE can be installed, trained, and operated without a keyboard on the system.

GAME PORT INPUT

The game port was chosen since it can be easily adapted to switches or puff-sip devices in place of the joy stick. ENABLE will support all functions in the system with only one input switch. In this mode (one switch), scanning of selected choices, letters or yes/no questions, is performed automatically by ENABLE. The scan rate is optional and changeable by the user as their ability to use the system improves. To further explain the use of the variable scan rate on the first choice, consider the following prompt: *12345
The prompt is asking the user to make a choice of one of the numbers, one to five, or request the next set of numbers. The system will scan the six choices of the prompt at the

scan rate specified. However, mentally the user will most likely scan all the choices initially rather than waiting to scan each one at the scan rate. The addition of a second switch adds direct control of the scan. The ease and speed of the system is directly affected as the number of input or sensing devices is increased. The program has, at this time, the ability to accept up to four switch inputs. These control the cursor in the forward, backward directions, select a character, or input a space. The system employs the moving space concept within the text selection process. The modular design of the software adapts nicely to more inputs if required.

ANTICIPATORY ARRAYS MODULE

This module is essentially the same as the NUCDC program from an external appearance standpoint. The major enhancement has been the addition of the latest anticipatory arrays based on the work of Shinghal and Toussaint. These new arrays in practice have received praise by those who used both systems. The system presents five letters and a space as a choice for spelling a word. The five letters are based on the most likely letters to follow the previous selection. If the letter desired is not one of the five choices then the next most likely choices are presented and so forth. Note the third most likely letter to follow a selection is not the third letter in the first five choices but is presented as the first choice in the second group of five choices. This optimizes moves since the number of moves to the third position of the first prompt is greater than the number of moves to position one of the second prompt. Likewise, the concept holds true for the fifth most likely letter and so on. The text processor allows full alphanumerics and all special characters (87 characters). These characters can then be formed into words, sentences, paragraphs and manuscripts which can be stored retrieved, changed, deleted and printed -- all through the use of one switch!

MUSIC COMPOSITION MODULE

This module allows the composition of music with a range of seven octaves, notes ABCDEFG, sharps, flats, notes ranging in length from 1/64 to whole notes (64 increments) with Normal, Legato, or Starcato, and a Tempo ranging from 32 to 255 quarter notes per minute, rest, etc. The musical score has the ability to be edited and stored.

APPLIANCE CONTROL MODULE

The appliance control module has the ability to control up to 128 appliances. Essentially it is able to turn on, off, or dim any device connected to the power distribution system (wall outlets, etc.) of the home.

TELEPHONY SUPPORT MODULE

Telephony support consists of a personalized directory, dialing, automatic switching to speaker phone, disconnect, and answering incoming calls. Non-verbals could use the telephony option to access various phone based services such as time and weather reports as well as, those "City Line" services utilizing touch tone input to qualify additional selections.

HELP FACILITY AND GAMES

Help windows are automatic with explanations of the functions being performed. A facility has been added to allow games to be selected and "played".

CONCLUSION

The concept of one input device through a computer which controls many devices is not new. It was first proven with the NUCDC software. This is an important economic consideration when planning communication and environmental control systems.

The goal of providing comparable features of the NUCDC system on an IBM PC was met and exceeded by new capabilities. These new features were primarily achieved by the increased capabilities of present day technology in both hardware and software. In a redesign process it is generally accepted that improvement should naturally follow.

ACKNOWLEDGEMENT

My thanks to Northwestern University. My appreciation to Charles Laenger and his staff at Kaiser Rehabilitation Center. A great deal of thanks to Al Price whose persistence expedited this project and to Telex Computer Products.

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COMPUTER LITERACY TRAINING FOR REHABILITATION PATIENTS

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Occupational Therapy Division, *Rehabilitation Engineering Program
University of Michigan Medical Center

INTRODUCTION

In this era of reliance on microcomputers for business, education, and personal use, it is increasingly important to have a basic understanding of their uses. This is even more critical for disabled individuals, because they do not have the physical ability to use the non-electronic tools that able-bodied people often use instead of a computer. Motorically disabled individuals need at least a basic understanding of available computer systems and their applications, in order to make an informed decision about the role that computers will play in their life (1).

Beyond this fundamental knowledge, the degree of computer literacy the user needs depends on the way in which the computer will be used. There are two main classes of functions that a computer can provide for a disabled user: *special functions* and *standard functions* (2). *Special functions* applications use the computer as a dedicated aid to overcome a user's specific functional deficit (e.g., augmentative communication). Even in a simple turnkey system, where the user interacts only with the special program, having a basic knowledge of how the computer works can help the user better understand how to use the special program and what to do when things go wrong.

Standard functions provide access to standard software, such as word processors, math scratchpads, and business packages. This allows a disabled individual to pursue a wide variety of vocational and/or educational opportunities that might otherwise remain closed. To fully exploit this potential, the user must have a high degree of computer literacy. He or she needs to understand the operating system well enough to manage files, organize disks, and move smoothly from one application to another. In addition, the *standard function* user needs to have an awareness of the computer marketplace since he or she will need to make consumer decisions on a potentially large number of application programs and hardware peripherals. Without some computer literacy, the user will not be able to purchase the system that is most appropriate for their needs or effectively use the system once it is purchased.

PROGRAM DESCRIPTION

In response to this need for computer literacy, a training program for rehabilitation patients has been established at the University of Michigan Medical Center. The program provides basic education regarding use, applications and access methods of personal computers. It has been necessary to start this program because alternative training methods typically fail to meet the needs of the disabled user. For example, seminars offered by computer retailers are often a good source of information, but they fail to address the critical issues of what a system can specifically do for a disabled person and how that person will access the system.

The program is designed to integrate the issues that specifically relate to the disabled population and those that are independent of user disability. It is provided jointly by Occupational Therapy and Rehabilitation Engineering to combine technological and therapeutic expertise. The program has five objectives:

- introduce each patient to the use of microcomputers
- demonstrate the potential advantages of using a microcomputer
- assess for the most efficient computer access interface
- provide sufficient knowledge of computer terminology and available hardware and software to make educated choices about system selection and purchase
- provide information and support for funding of specified equipment

Due to the variety and complexity of patient needs, all the objectives listed are not appropriate for every patient. Therefore, the program is structured in a modular format, to allow patients and staff to choose those areas that apply in each case. (See Figure 1.) The first module is an *introduction* usually provided in a group setting. The group provides peer support for what is frequently an intimidating topic and the interaction among the patients often generates interest for continued participation in the program. The remaining modules are selected individually based on patient need and interest. They are:

- *needs assessment*, to identify the potential uses for a computer in daily life
- *special inputs*, to assess for most efficient input methods
- *system operation*, including hands-on experience
- *sample applications*, exploring word processing, spread sheets, data bases, personal finance, and networking
- *system purchase*, covering questions to ask a vendor, funding sources to explore, a checklist for making software/hardware selections and where to look for user support groups

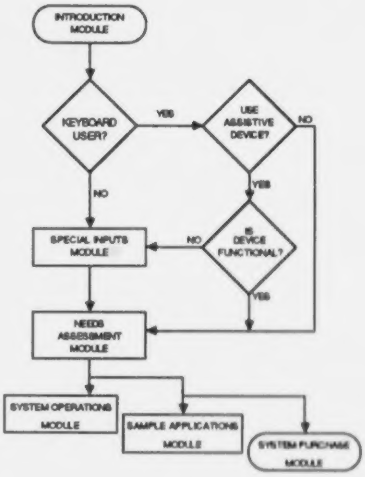

Figure 1. Modular Structure of the Program

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CASE STUDIES

Case 1

DR is a C2 ventilator dependent quadriplegic. He had no knowledge of computers prior to participation in the program. DR participated in the program as an inpatient during a hospital readmission. Due to his extensive motor impairments, establishing and training the most efficient interface was a high priority, so the special inputs module was emphasized.

Using knowledge gained from the program, DR identified specific application areas including word processing, personal business and financial management. He could make educated decisions during system selection based on his individual needs and preferences. The program goals were met by producing an educated consumer with a basic level of computer literacy.

DR also helped to identify potential problems with the program. Due to limited resources, DR has been unable to secure funding for desired equipment and follow-up services. Our attempts to assist DR by providing letters of need to Medicaid and contacting his social worker in an effort to locate alternative funding and support services were unsuccessful. Fortunately, as an educated consumer, DR is able to serve as his own advocate and continue his search for funding.

Case 2

CS is a C6-7 quadriplegic who had limited contact with computers and a basic knowledge of potential applications. CS began the program as an inpatient during his initial rehabilitation, receiving only the introductory module. CS expressed interest in continuing the program, but requested that he do so after discharge in order to focus on his medical and self care needs as an inpatient. Fortunately, CS has insurance that supports outpatient services, and there have been no difficulties accomodating his request.

As an outpatient, he gained hands-on experience with the IBM PC and Apple Macintosh and explored sample applications programs. Because CS is an efficient keyboard user, the special inputs module was edited to include only an orientation to abbreviation expansion methods. Specific application areas identified during his needs assessment included word processing; personal finance with capability to track investments, rental properties, and assist with tax preparation; communications software; and recreational software.

CS has elected not to purchase his computer system until his vocational goals are more well-defined. However, his computer literacy training has given him the skills to make independent purchasing decisions at the appropriate time.

DISCUSSION

Overall, the computer literacy program has been quite successful in meeting a wide variety of patient needs, due to its modular structure. Most patients have responded very favorably to the program.

However, two areas of concern have been identified. First, computers and related training are not considered to be medically necessary by most third party payers and are therefore not frequently funded. Accordingly, the purchasing module has been modified to include not only system selection, but also strategies for obtaining funding and ongoing training.

The second issue is the effectiveness of providing the program on an inpatient vs. outpatient basis. The program is currently used primarily with inpatients. This approach avoids the difficulties of obtaining prior approval for services. Patients with limited insurance often would not be able to participate in the program if it were available solely on an outpatient basis. However, this model is being reevaluated for two reasons. First, reimbursement policies are reducing the length of hospital stays for rehabilitation patients, which limits the number of goals a patient can realistically achieve. Second, a rehabilitation inpatient is often overwhelmed with medical, psychosocial, and self-care issues. After discharge, the patient is no longer "acute" and may be better able to assimiliate the information presented. In addition, an outpatient typically has a more realistic understanding of his/her needs as a disabled individual and may be more receptive to computer use. One alternative to the inpatient model is to present only introductory information to inpatients, to generate interest for more specific training after discharge.

FUTURE GOALS

The computer literacy program is still under development. Even though it is now being used with a variety of patients, there are a number of items planned which should enhance the overall effectiveness of the program. These are: implement the introductory module as a regular part of rehabilitation for all appropriate patients; develop computer based tutorials for the modules to reduce staff time and increase the cost effectiveness of the program; establish a local users group for disabled computer users; identify more funding sources; document effectiveness of the program; and provide greater access to microcomputers for all patients.

CONCLUSION

There is no doubt that a good basic knowledge of microcomputers will enhance the vocational opportunities for many severely disabled individuals. The computer literacy program described is designed to both provide some basic knowledge and demonstrate the variety of applications for which the microcomputer can be used. Once the disabled user understands these concepts, more conventional training channels for specific applications can be pursued.

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LEARNING TO RECALL/RECALLING TO LEARN:
EFFECTIVE SOFTWARE FOR TEACHING COGNITIVE STRATEGIES

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INTRODUCTION

The most typical application of technology found in classrooms is the microcomputer. Unfortunately, the computer's use is often limited to presentation of information that is available through other means. This severe under-utilization of the computer's capabilities jeopardizes the allocations of money and time currently devoted to classroom computerization, since research has shown minimal difference between teacher instruction and computer instruction of this nature (3,4).

A more appropriate use of classroom computers is to make available instruction that is not feasible when presented in any other way. An example of this is the software designed by the authors to assess and assist in remediating memory process deficiencies. Since memory underlies all other academic areas, improvement in memory processing has the potential for generalized positive impact.

This software compacts the voluminous materials and unwieldy procedures used in laboratory examinations of memory processing into a set of disks. The instructional system has the capability to present the task at a variety of levels of difficulty, determine the appropriate level at which to begin intervention, and then proceed with a finely-tuned instructional sequence founded on the results of numerous cognitive processing investigations documented in the literature (1,2).

The task involves recall of items in a list, yet the approach is not traditional. Students are required to use a circular recall strategy rather than a serial recall strategy that permits an analysis of their cognitive strategy use. A person who is successful at circular recall typically rehearses the last letters in the list in such a way that they are committed to short-term memory (thus permitting them to be recalled first with minimal effort) and the first letters in a way that will commit them to long-term memory (permitting them to be recalled later). Data were gathered on accuracy and pause time. The latter gives some indication of students' strategy use by revealing the pattern of inter-item pausing, which is an indicator of the amount of differential rehearsal devoted to each item in the list.

The software also accounts for the needs of students who have difficulty with traditional instruction by circumventing the necessity for keyboard input. All selections are made using a light pen so that the student need never take eyes away from the monitor. To reduce attention difficulties, the screens are designed simply, and potentially-distracting graphics and animation are withheld until the reward sequences. All text instruction and feedback can be presented simultaneously in digitized speech to assist those students with poor reading skills.

The software capitalizes on the data analysis capabilities of the computer. It conducts on-line computations to determine if student performance compares favorably to a predetermined "ideal". This determination directs the system to continue with training (and place the student in the appropriate component of training) or to proceed on to new material. All of this data is made available to the teacher/student in graphic and/or tabular form, and narrative interpretations of student performance are also available.

METHODS

The instructional software was field-tested with 60 students aged 12 through 14. One-third of the students had mental retardation, one-third had learning disabilities, and one-third were non-handicapped. All of the students received a computer-based assessment of their ability to recall sequences of numbers, and half of the students received the computer-assisted instruction in the use of memory strategies.

RESULTS

The data indicate that the instructional package was effective in improving the memory capabilities of the students. For students in the training group, regardless of subject classification, absolute gains from pre-test to post-test were made. For example, students with mental retardation gained .7 level, with the control group making no gain. Learning disabled students gained 1.4 levels while the control group gained .1 level. The nonhandicapped group gained 1.6 levels and the control gained .2. Overall, students with mental retardation did not demonstrate the same degree of improvement as the other subjects. Interestingly, the learning disabled students reached the same level of performance as the nonhandicapped students but required more practice to achieve it.

DISCUSSION

In addition to the objective data, much was learned about the manner in which students approach computer-based instruction and about the individual learning styles demonstrated by the students. These subjective impressions have led to the conclusion that some system features are especially important for a specific population, and some features that are helpful for one group of students may be detrimental to efficient learning with others.

Overall, students enjoyed their interaction with the software. Many were motivated to improve their performance by the chance to play a challenging video game at the end of the instructional module; however, many were intrinsically motivated by the task itself. Some students who had shown little enthusiasm in the traditional classroom setting worked diligently at the computer-based task, and students who typically had short attention spans for schoolwork maintained uninterrupted engagement with the computer for 45 minutes or longer.

CONCLUSIONS

This project established that it is feasible and worthwhile to develop educational software that capitalizes on many of the powerful features of microcomputers that are typically disregarded in classroom applications. More specifically, it underscored the effectiveness of the keyboardless interface, concurrent text and spoken output, and rather stark screen presentation for instructional segments. The project also showed that it is possible to translate sophisticated and complex pedagogical procedures into a format that is both effective and appealing.

ACKNOWLEDGEMENTS

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A MINIATURE HALL-EFFECT JOYSTICK TRANSDUCER: THEN NEXT GENERATION

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ABSTRACT

The design of an existing dual-axis continuous output joystick transducer was modified to decrease its size, optimize its linearity, minimize the crosstalk between the two axes, and simplify the manufacturing process. A history of the transducer development, some of the current design considerations, and some results from a prototype transducer are presented here.

INTRODUCTION

In the early 1970's, the Systems Cybernetics Group at Case Western Reserve University (CWRU) developed a two-axis position transducer based on strain gages, to monitor shoulder movement (1). In the late 1970's and early 1980's, a second generation of shoulder movement (joystick) transducers was developed at CWRU. The transducer was based on the inductive coupling between a driver coil and two pairs of pickup coils (2,3,4). Two designs were developed. In one design, the driver coil was wound on a ferrite core that was mounted inside a plastic ball. The ball was mounted in a spherical cavity, and a rod was attached to the ball. Movement of the rod caused rotation of the ball relative to the cavity, which was sensed by the two pairs of pickup coils. In the alternative design, the driver coil encircled the ball cavity, and only the ferrite core was mounted inside the ball. In the mid 1980's, a third generation position transducer was developed based Hall effect sensors and a permanent magnet (5). The configuration was similar to the previous design, but two pairs of linear Hall effect sensors were used in place of the pickup coils, and a permanent magnet was used in place of the driver coil and ferrite core. The new design was intended to simplify the manufacture, reduce the cost, and increase the reliability of the transducer. This paper discusses some of the design configuration considerations of the hall effect joystick transducer, and how they affect the size of the transducer, and the linearity of the output.

METHODS

Several practical constraints considerably limit the design of the Hall effect transducer. These constraints are: 1) The transducer should be as small as is practical; 2) A permanent magnet mounted in a ball will be used to generate a magnetic field; and 3) Pairs of hall sensors will be used in a differential configuration to detect changes in the magnetic field. Microswitch 3SSEA1 linear Hall sensors are the sensing element used in the design. They are available on a .2"x.3" ceramic substrate, and are approximately .05" thick. The magnets considered in the design are .25"x.25" and .125"x.125" cylindrical Alnico magnets. There are many degrees of freedom in the design, including: the distance between the sensors, the inclination of the sensors relative to the magnet, the distance between the sensors and the magnet, the size of the magnet, and the center of rotation of the magnet. The effects of these parameters were examined both empirically and theoretically.

RESULTS

Figures 1, 2, and 3 show the output characteristics of one particular configuration of sensors and magnet. This configuration uses four hall sensors, arranged in two pairs, with a separation of 0.2" between the two sensing elements of each pair. The magnet is a 0.25"x0.25" cylindrical magnet, with the center of the magnet at the center of rotation of a ball. The magnet is approximately 0.25" from the sensors. With this configuration, a cylindrical transducer of 0.5" diameter and 0.675" length is feasible.

Figure 1 shows both the X-axis and the Y-axis outputs versus the X input angle. The X-axis output is related to the X input angle by a nearly linear function, with a slope of 3.06 mVolts/degree and a correlation coefficient of 0.99999. The Y output changes very little with movements along the X axis. Figure 2 shows both the X-axis and the Y-axis outputs versus the Y input angle. The results are similar, with the Y output related to the Y

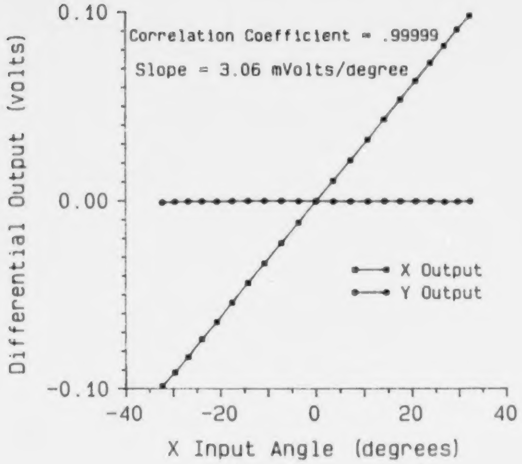

Figure 1

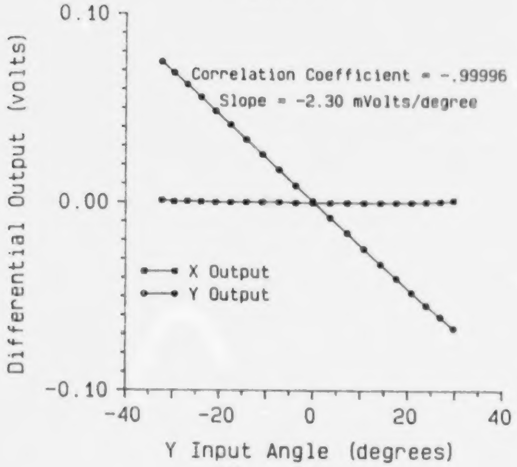

Figure 2

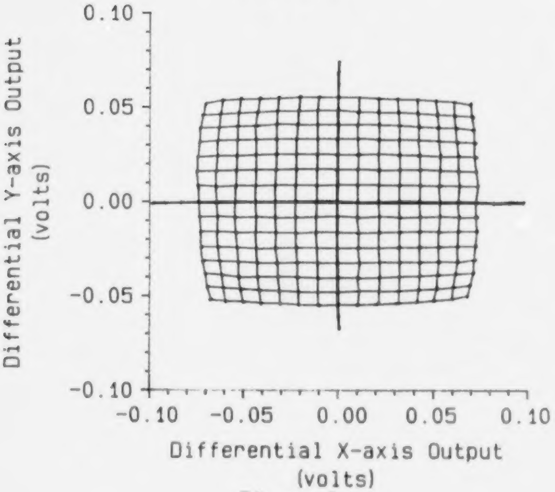

Figure 3

input angle with a slope of 2.30 mVolts/degree and a correlation coefficient of 0.99996. The sensitivity of the Y axis is lower because the Y-axis sensor pair is slightly further from the magnet. Figure 3 shows the X-axis output versus the Y-axis output when the rod attached to the transducer traces out a rectangular grid pattern at 1 cm intervals, over a ±7 cm range, with a rod length of 15.8 cm. The range extends further than 7 cm along the central axes. Three independent trials are superimposed along the two central axes.

DISCUSSION

There are two approaches involved in optimizing the characteristics of a transducer: the empirical and the theoretical. Both approaches have yielded useful insight into the sensor and magnet configurations. The design modifications have given us a transducer that is smaller than the previous design, (0.5"x0.5"x0.675" instead of 0.7"x0.7"x1.6"), that is more linear over a wider range, and that has some manufacturing advantages over the previous design.

ACKNOWLEDGMENTS

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COMPUTER-AIDED DESIGN OF CUSTOM ORTHOPAEDIC FOOTWEAR

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INTRODUCTION

The requirement for custom orthopaedic footwear can result from primary disorders such as trauma or secondary problems related to systemic diseases (e.g. arthritis). While the less severe cases can be managed by shoe modifications, custom orthopaedic shoes are often the best solution for severe cases. The manufacture of these shoes is performed by skilled artisans whose numbers have shown significant decrease over years. As the elderly continue to form a larger segment of our population, the demand for custom shoes is increasing. The net result is an increase in both cost and delivery time.

In 1984, the Research Triangle Institute conducted two workshops to investigate the role of CAD/CAM in the orthopaedic footwear delivery system (1). Two major conclusions were derived. The first was that a computer aided system had the potential to improve the quality of service while reducing costs and delivery time. The second major conclusion was that a CAD/CAM system for orthopaedic footwear should include the following components: 1) a 3-D foot shape digitization system, 2) a CAD station for the input of other quantitative data and prescriptive modifications, 3) a numerical control system for production of the shoe last and, 4) a computer aided pattern layout system.

A potential solution for meeting these requirements is being developed. It consists of a CAD system for shoe lasts based on a series of parametric surface elements. Parametric surfaces can represent a complex but smooth shape with a minimum amount of data. These surfaces are used in the computer aided design of various shapes from ship hulls to garments. Each element is represented in the computer mathematically by a bicubic polynomial of two parameters. The coefficients of the polynomial are calculated based on the geometry at each corner of the element. Continuity between neighboring elements can be enforced resulting in a smooth surface. While the use of parametric surfaces is a logical choice for the design of shoe lasts, what is perhaps unique about this approach is that it requires the foot to be measured according to a unique protocol.

METHOD

In the CAD program, both the foot and shoe last are represented by a pre-defined arrangement of surface elements and nodes. The nodes are points on the surface which designate the corners of the elements. The spatial coordinates (x,y,z) and surface normals (**n**) at each node uniquely describes the shape.

To determine a suitable number of nodes and elements to define shoe last and foot shapes a Fast Fourier Transform was performed on the cross-sectional data of both shapes. The results showed that on a sample shoe last, there was no significant information past the 4th harmonic. While the foot shape showed higher harmonics, particularly in the toe area, these were not "passed" to the last shape. Based on these findings, a representation for the shoe last was devised containing 52 nodes and 44 elements.

Foot Measurement

The protocol used for measuring the foot is as follows. The nodes are marked on the dorsal surface of the foot with a marker. The subject then stands in foam blocks which leave a weight-bearing impression of the plantar surface. While standing in the blocks, a 3-D digitizer is used to collect the coordinates and normals at each node. The subject then steps out of the blocks and the nodes located on the plantar surface are measured from the resulting impressions. The data is downloaded to a computer where the parametric surfaces are generated. Figure 1 shows a graphical representation of a foot measured in this manner. The nodes are located at the intersection of the bold lines.

Computer-Aided Design Procedure

Once a foot shape has been input into the CAD program, a suitable shoe last shape must be generated. The approach followed is based on the Reference Shape Modelling approach used in the computer-aided design of trans-tibial amputees (2). A reference shape is selected

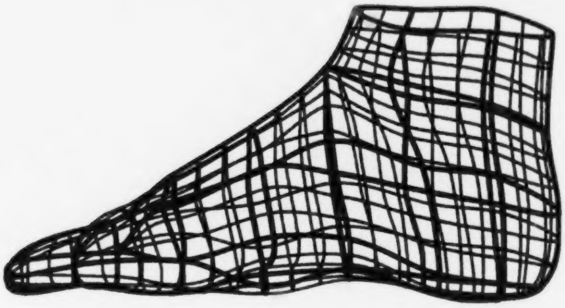

Fig. 1 - Parametric Surface Representation of a Foot.

from a library of shapes based not only on the shape of the foot, but also on the biomechanical correction desired and the intended style and function of the footwear.

The reference shape is then scaled to fit the known dimensions of the foot; the resulting shape being known as the primitive last shape. The primitive shape is displayed on a graphics workstation screen. The operator can then compare the last shape to the foot shape and, if necessary, make changes to the primitive shape by moving certain nodes. Once a satisfactory shape has been achieved, the program generates code for a numerically controlled milling machine that "carves" the last. An optional feature allows the operator to design leather cutting patterns on the graphics screen which can then be plotted on a pen plotter.

DISCUSSION

There are a number of advantages to the approach presented here. The major advantage is that parametric surfaces inherently produce smooth shapes. To produce footwear that is both stylish and functional, the last must have a smooth surface and clean lines.

A second advantage is the small amount of data required to define the shape. This allows modification of the shape while still maintaining smoothness. An example of such a modification is the provision of relief around the first metatarsal head for a subject with halux valgus. This could easily be accomplished by moving certain nodes on the medial surface of the last outwards with the resulting relief being blended into the existing shape.

In the present system, the only method of changing the shape is to change the location or orientation of a node. This will have an affect on all elements that use the node. This makes small "local" modifications difficult. A scheme is being developed by which smooth "patches" normal to the parametric surface can be added or subtracted. The patches can be of any size and height and may cross the boundary between neighboring elements thus allowing complete flexibility in local modifications.

The method used for measuring and representing the foot was chosen for its compatibility with the Reference Shape Modelling approach to the design of the last. This approach requires that certain measurements between specific anatomical points (e.g. the width across the metatarsals) be known. As all required landmarks are also designated as nodes, and therefore measured, the CAD program can easily extract critical anatomical measurements from the data base.

CONCLUSION

Parametric surfaces allow accurate descriptions of both foot and shoe last shapes, inherently provide the smooth surfaces required of shoe lasts and comprise quantitative information about the location of key anatomical landmarks. Coupled with the Reference Shape Modelling procedure, it is anticipated that functional shoe lasts can be produced to manage a range of foot disorders.

ACKNOWLEDGEMENT

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A TEMPLATE MODEL, MICROCOMPUTER BASED EMG BIOFEEDBACK SYSTEM FOR USE WITH HEMIPLEGIC PATIENTS

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INTRODUCTION

Electromyographic biofeedback has been successfully employed as a therapeutic modality in the treatment of a wide range of neuromuscular pathologies including hemiplegia (1,2). Biofeedback consists of giving an individual real-time information concerning a pre-selected physiological parameter under central nervous system control. Thus the ability to provide adequate and meaningful feedback to the patient is of prime concern in the planning of biofeedback treatments . Findings from the motor learning literature strongly suggest that feedback used in conjunction with a well defined template or representation of the desired output provides the most conducive learning situation (3,4). The purpose of the project addressed here is to outline the development and use of an EMG biofeedback system based on a "template-feedback" model of motor learning for use with hemiplegic patients.

The rehabilitation of hemiplegic patients who show a marked paresis of an upper limb present an ideal clinical situation in which to employ the "template-feedback" model. The goal in treating such a patient is to establish a level of muscle activity in the paretic limb comparable to that of the unaffected side. Traditional EMG biofeedback interventions would present the patient with an ongoing record of their attempted muscular contractions via auditory and/or visual modalities. With instruction and practice the patient gradually learns to augment the electrical activity of the paretic muscle. The system described here will allow the subject to view the EMG activity recorded from the unaffected limb (template) while attempting to produce the same pattern of EMG activity (biofeedback) with the paretic limb. It is to be expected that such a manipulation will facilitate the re-establishment of motor control in the paretic limb.

EXPERIMENTAL ENVIRONMENT AND DATA ANALYSIS

The electrical activity of the contracting anterior deltoid muscles is recorded by surface electrodes placed 2 cm apart at a point approximately 6 cm below the acromio-clavicular joint during a 5-sec isometric shoulder flexion task performed against a fixed resistance (which allows for the quantification of the resulting torque). The recorded signal is amplified (DISA 15C01) and filtered (-3dB at 10 and 500Hz) and subsequently sampled at 1000Hz by an IBM-PC/AT. The signal is rectified, smoothed (6Hz) and displayed on-line in a pre-selected colour on a monitor positioned directly in front of the subject. Following verification of the integrity of the signal, the curve is normalized relative to its maximum value and presented to the subject together with graded X-Y axes and labels which provide both the patient and clinician with a vivid representation of the entire contraction. The patient is then required to perform a similar contraction with the paretic limb and this is displayed in a normalized (relative to the value of the contraction of the healthy limb) form on the same monitor. The patient can then view both outputs and the clinician has the opportunity to explain and interpret the performance. The two contractions represent one training trial. A sample of the monitor display is illustrated in Fig 1.

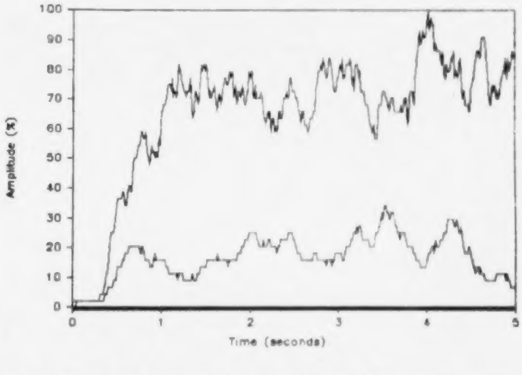

Figure 1. A view of the patient's monitor. The upper curve represents the electrical activity of the healthy limb, the lower curve the paretic limb. Both curves are full wave rectified and smoothed. 100% on the Y axis represents 880 microvolts.

Following each training trial statistics such as: the integrated, peak and time to peak EMG are generated for individual contractions. In addition, the difference between the two curves (area) is computed for each one-second interval. These data are immediately available to the clinician on a separate monitor and are stored for subsequent analysis. Both EMG curves are stored on diskette for recall during the following sessions for comparative purposes. The clinician is able to store (on hard disk) the raw data for either part of or all of the 5sec signal. This is transferred to a mini-computer (off-line) for subsequent analyses. Details of the laboratory configuration and software has been described elsewhere (5) but are illustrated in summary form in Figure 2.

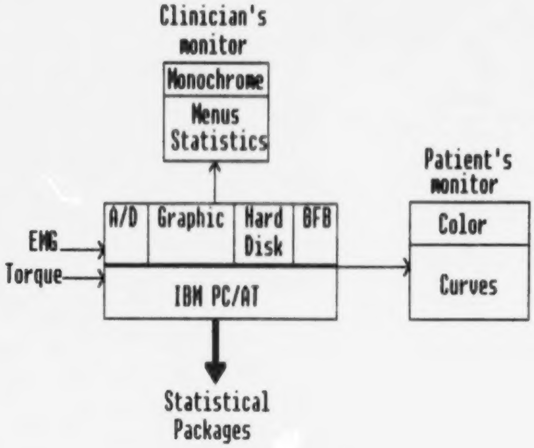

Figure 2. The biofeedback experiment is run with a microcomputer equipped for on-line signal acquisition(A/D), data processing and graphic presentation (Graphic) . Part of the experimental data is stored on the hard disk for off-line analysis. Special software (BFB) was written to run the experimental protocol through menus displayed on the clinician's monitor. On the patient's monitor, only the curves resulting from the contractions are presented.

CLINICAN APPLICATION

This EMG biofeedback system is currently being used to evaluate its validity as a clinical tool in the treatment of the paretic upper limb. Those patients selected for the EMG biofeedback training program followed a series of 12 training sessions (in addition to pre- and post-evaluation sessions performed without biofeedback) which focused on the behavioral objective of increasing the degree of contraction - as evidenced by the integrated EMG. Our clinical experience suggest that the "template-biofeedback" system is user-friendly for both the clinician and the patient and provides a motivating work situation. The patients report that the graphic display is easy to understand - an important factor in this population. Furthermore the clinician is better able to observe performance changes and control the training session.

ACKNOWLEDGEMENTS

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Rural Rehabilitation
Réadaptation en milieu rural

ICAART 88 - MONTREAL

RURAL REHABILITATION - A REWARDING EXPERIENCE

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Community Occupational Therapist

The purpose of this presentation is to show that rural rehabilitation can be and is an exciting place to be. Even though rural areas often do not have access to the latest 'state of the art' technology, rural therapists are innovative and diligent in obtaining aids and devices to enhance the daily lives of handicapped individuals living in their areas. Through the use of a slide presentation I hope to give you a feel for the challenges and rewards of being an Occupational Therapist in Northern Alberta.

I am a member of a mulit-disciplinary team working for the Coordinated Home Care Program of the South Peace Health Unit in Grande Prairie, Alberta, a community of 25,000, 300 miles northwest of Edmonton. Our team of nurses, homemakers, physiotherapists and occupational therapists, covers an area of 13,000 square miles and serves a population of over 56,000. Our caseload averages 400-500 clients per month and of these we see 50-60 who have a variety of disabilities and chronic illnesses. The ages range from birth to 98 years.

One of our primary responsibilities is to ensure that individuals requiring aids and devices provided for by the Alberta Aids to Daily Living Program, are properly assessed, provided with appropriate aids and instructed in their use. We supply a multitude of bath seats, grab bars, raised toilet seats, hydraulic bath lifts, commodes, hydraulic lifts and wheelchairs, to name a few. We always have a tool box on hand and are adept at installations and minor repairs.

In our community there are many physically challenged people who rely on technology to make their lives easier. It is always a challenge to help an individual choose the right equipment so that it is best suited to their needs and environment. Power mobility units must be chosen to take into consideration rough ground and farm yards, small trailers and log homes. Emergency call systems must be carefully chosen with rural party line phone systems in mind. Computers are now an important item for handicapped people, whether it be for communication purposes or career choices. We are often involved in helping to obtain funds to purchase computers and other needed items.

One of the long standing probems in our community has been the lack of accessible housing for the wheelchair-bound handicapped adult. After several years of dedicated work and frustration a group of handicapped individuals, their families and involved professionals formed the Grande Prairie Residential Society. In May of 1987 the group was able to procure a mortgage from the Federal and Provincial Governments who joined together for the first time to subsidize a project of this nature. We were provided with a $693,000 mortgage at 2% interest by Alberta Mortage & Housing, co-signed by Canada Mortgage and Housing, to build five side-by-side duplexes. In addition, the group raised a further $90,000 from the community to provide for needed extras not provided by the mortgage. In December of 1987 the housing project opened, allowing 10 handicapped individuals, some with families, the opportunity to choose where they wanted to live; some for the first time in their lives. One lady, suffering from Cerebral Palsy and confined to a wheelchair, was in a nursing home for over 21 years and finally being able to choose to live on her own was a very special dream come true.

The Home Care Program applied for and received funds from the Alberta Government to provide personal care and homemaking help for people in the housing project. We are able to provide up to 21 hours of personal care and 10.5 hours of homemaking help per week to an individual. For those without spouses who require 24-hour assistance, Social Services has provided funding to allow them to hire full-time live-in aides. For some of these people we provide relief when the aides have days off.

As committee members, consultants, and fund raisers we were heavily involved in the designing and implementation of this project. The units were all built with wheelchair users in mind; they have wide hallways and doorways. The kitchens were designed with low counters, counter-top ranges, built-in ovens and side-by-side freezer/fridge units. The large bathrooms have wheel-in showers with fold-down benches. Safety rails are positioned around the shower, tub and toilet. The sink is wheelchair accessible. All fixtures have single-lever faucets and all doors have lever handles. Closets have rods at an accessible height, light switches and plugs are lower and all windows are set low to allow a 'normal' view. Washers and driers are font opening and all interior doors are sliding.

For individuals in the project who required special technical aids we contacted the Easter Seal Ability Council for funding assistance. One young man, suffering from Cerebral Palsy, has an automatic door unlocker installed in his unit. He need only punch in a combination to open his door. He also uses an emergency call system in conjunction with his telephone so that pushing one button notifies three friends and neighbors that he is having difficulty and needs assistance. Having this alternate housing available has allowed this young man to move from a small northern community to pursue his training in computer science yet allows him to be close enought to home to maintain close contact with his family.

Others in the units use speaker phones, hydraulic bath lifts, several have computers or are training on computers and hope to get their own. We are now trying to obtain a tash unit to enable one young girl to control her lights and appliances.

It has been a very rewarding experience as a therapist to have been involved in this project. It is especially gratifying to know that a rural community can offer handicapped individuals some of the choices that seem so much more prevelant in large urban areas. Technology is rapidly improving the quality of life for many handicapped persons all across Canada. It is certainly encouraging to know that rural Canadians are able to enjoy the same advantages as urban ones and that it is no longer necessary for handicapped individuals to live in large centres if they choose not to.

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BRINGING BIOCYBERNETICS TO RURAL HANDICAPPED CHILDREN AND ADULTS

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INTRODUCTION

Biocybernetics is the study of methods whereby handicapped individuals are prepared to meet the challenges of life. This includes preparation in the areas of daily life, education, work, and recreation. Included are the multidisciplinary efforts which are necessary to provide handicapped individuals with appropriate adaptive equipment, mobility aids, communication assistive devices, seating/wheelchair modifications, and environmenatal control systems. The goal is to provide the rural handicapped individual with maximum social integration in his/her natural environment and non-handicapped peer group.

The need for this project was based on the assumption that rural handicapped individuals and existing service providers in rural/small schools have great difficulty in obtaining tailor-made assistive devices because of low incidence, natural geographic constraints, funding inadequacies, transportation inadequacies, and problems with recruiting highly trained specialists. It appeared that a substantial solution to this problem would lie in linking specific rural/small school systems with the combined efforts of various Texas Tech Centers through provision of a Laboratory for Developing Orthotic and Assistive Devices for Handicapped Individuals Living in Rural Areas. It should be noted that Texas Tech, as a research facility, has all of the facilities needed to provide high quality rehabilitation services, but that these sophisticated facilities are clinic-bound. It was our belief that we had to take our researchers and clinicians into the schools, homes, and communities to work with the pre-existing facilities, personnel, and service delivery systems (1). We think similar conditions exist throughout the nation, and that this laboratory can serve as a prototype (2,3,4,5).

METHODS

The project was undertaken in the Fall, 1987 as a combined effort of the Texas Tech University Center for Applied Research in Engineering, Office of Research Services, Center for Excellence in Education, and Health Sciences Center. The project soon came to include numerous other university and community entities. Senior students in the areas of electrical engineering, industrial engineering, and mechanical engineering were brought together, through assigned coursework, with graduate students in the area of special education serving multiply handicapped individuals. This combined effort provided the man-power needed to form an on-going laboratory. Funds were secured from local, state, and national sources for a preliminary effort, with hope for additional funding as the project demonstrated effectiveness. Approximately 20 senior engineering students joined 10 teams of educators (3 per team) presently serving rural handicapped individuals while working toward an advanced degree. These teams went into the homes, schools, and communities of 10 individuals identified as having need for services based on professional educator expertise. Co-operation from the individual, his/her family, and other service providers was assured prior to beginning. An assessment device was developed through the combined efforts of the engineering and educational professionals involved. The senior engineering students and graduate education students met several times with the handicapped individual and the significant others in his/her life in assessing and prioritizing needs. The engineering students then developed the devices or searched commercial avenues for pre-existing devices. It should be noted that even when commercially available devices were found, none was satisfactory without some modification. The engineer and educator then provided the handicapped individual and significant others with training in the use of the device and with suggestions for modifications. The assurance of follow-up services for modification/repair was given.

RESULTS

Measurable results are as follow: (1) Ten rural handicapped individuals have been provided with custom designed adaptive devices. (2) Twenty senior engineering students have han first-hand experience in applying their skills to a diverse handicapped population. (3) Thirty graduate educators have had experience in using engineering expertise in solving problems faced by handicapped individuals. (4) Engineers and educators have been allowed the opportunity to appreciate each other's contribution to service delivery. (5) Community and university resources have had the opportunity to combine in making the lives of handicapped individuals better.

DISCUSSION

The simplicity of this project lies in its conceptualization--it is common sense that disciplines working together and that universities and communities co-operating can better serve handicapped individuals. The complexity lies in implementation. Persons dedicated to the concepts of multidisciplinary teamwork sharing of knowledge, and release of professional boundaries are necessary at each level of implementation in order to best serve the rural handicapped individual in this system.

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FARMING FOLLOWING A SPINAL CORD INJURY

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INTRODUCTION

In 1979 a young farmer who had recently experienced a high level spinal cord injury (SCI) contacted the Department of Agricultural Engineering at Purdue University seeking information that would assist him in continuing to farm. That unusual inquiry eventually led to the establishment of the Breaking New Ground Resource Center which has become widely recognized as a major resource for farmers and ranchers with serious physical disabilities. Early inquiries to the Center revealed that the number of farmers with permanent SCI's was substantially greater than was anticipated. Throughout the existence of the Center, individuals with SCI's have comprised one of the major groups utilizing the services of the Center. The purpose of this paper will be to summarize the experiences gained through contacts with this small but largely under served population and share a few suggestions for improving the accessibility of the agricultural workplace to those with SCI.

SCOPE OF THE PROBLEM

No one has a definitive answer as to the number of farmers, ranchers, agricultural workers, and members of their respective families who have experienced SCI's and chosen to remain in an agricultural setting. In 1981 a study done at Purdue by Tormoehlen (1) of 500 randomly selected farm operators did not discover any evidence of SCI. Neither did evidence of paraplegia or quadraplegia show up in the review of other studies completed by Tormoehlen.

However, in 1986, Wilkinson (2) completed a mail survey of 500 farm operators with unknown physical handicaps who have utilized the services of the Breaking New Ground Resource Center. The sample was drawn from 36 states and 6 Canadian Provinces. It was comprised of approximately 95 percent males with an average age of 44. Table 1 presents the findings regarding the distribution of disabilities reported by the 186 respondents.

Table 1. Distribution of Farmers by Type of Handicap (Wilkinson 1987)

Handicap	Number of Farmers	Percent of Farmers
Paraplegic	68	36.4
Upper Limb Amputee	29	15.5
Quadriplegic	23	12.3
Lower Limb Amputee	18	9.6
Musculoskeletal	14	7.5
Neurological	14	7.5
Lower Leg Impairment	9	4.8
Respiratory	6	3.2
Vision	5	2.7
Polio	5	2.7
Hearing	4	2.1
Back Problems	4	2.1
Muscular Dystrophy	3	1.6
Cardiovascular	2	1.1
More Than One Handicap	28	15.0

Experience has suggested and the survey confirmed, that those who contact the Center tend to have more severe disabilities. Consequently this data could not be applied to the general farm and ranch population to project the incidence of SCI in the general farm population. However, it is believed that for every individual who is proactive in seeking rehabilitation services, there are many others who remain unserved, isolated from its potential benefits.

In no way can it be concluded that this population is of significant size to demand the reallocation of substantial resources to address their unique vocational problems. However, considering the narrow scope of services provided by the Breaking New Ground Resource Center this group has been identified as a primary target population. Again, experience has shown that there can be a wide variety of spin-offs to other, less severely disabled individuals, through the reduction of accessibility barriers to those with SCI.

BARRIERS TO FARMING WITH A SPINAL CORD INJURY

Farming has traditionally been a highly labor intensive occupation. It has demanded strong backs, unhindered mobility and considerable physical endurance. An evaluation of the essential work-related tasks completed on typical farm operations would reveal many that would be extremely difficult for someone with a SCI to complete. For example, handling livestock, climbing grain bins and silos, operating and servicing equipment and handling bulky supplies and crops.

However, over the past 25 years agriculture has become increasingly mechanized with tremendous opportunities for improved accessibility to accommodate the limitations of an individual with a SCI. The use of electronics, centralized controls, hydraulics, monitoring systems, computerization and enterprise specialization have opened the door to many potential modifications. There is no good technological justification to discourage on individuals with a SCI from continuing to play an active role in a farm or ranch operation.

ALTERNATIVES TO CONSIDER

A farmer or rancher who has recently experienced a SCI has several options to consider in the process of returning to work. These include:

1. Consideration of alternative, off-farm, employment that would utilize skills and knowledge learned prior to the SCI. This is an appropriate topic to address with the final decision being influenced by a number of non-technology related reasons including complicated health-related problems, economics, and lack of family support.
2. Evaluation of essential tasks associated with the present operation of the farm and reassignment of job responsibilities. Jobs that are essential, but present a considerable barrier to the individual with the SCI or are too costly to modify might be best assigned to someone else. If a substantial number of jobs would require costly modifications, consideration might be given to changing the nature of the operation while still utilizing existing resources. For example, switching from milking cows in a stanchion barn to installation of an accessible milking parlor or changing from baled hay to silage.
3. For those tasks which are determined to be essential for the individual with the SCI to complete, modifications to the necessary tools, processes, and job sites could be implemented. The question is not whether or not a specific modification can be made but rather is such a modification the best use of resources and does the desired task make the best use of the individual's skills, knowledge, and interests.

EXAMPLES OF WORKSITE MODIFICATIONS

The Wilkinson study indicated that service and maintenance of agricultural equipment was a serious barrier for almost 50 percent of those responding. There have been numerous approaches to this problem with each being dependent upon the individuals' physical abilities, economic resources, type of equipment involved and the nature of the farm operation.

If repairs are done on the farm, a well laid-out farm shop with a smooth working surface is essential. If heated, it also provides a place to work during the off-season. A telephone in the shop provides communications for ordering parts and services and conducting other business.

There is no reason why most farmers with lower level SCI's cannot complete basis maintenance tasks such as changing the oil, servicing filters, lubricating equipment and completing many small repair jobs on tractors and combines. The wheelchair does not have to totally restrict mobility when doing work in and around equipment. With the use of crutches, braces and mobile standing aids most service points can be reached. A major exception, is servicing the engine compartment on large tractors, combines and self-propelled harvesters. Engine compartments are typically 6-10 feet off the ground and often demand considerable flexibility. It might be best to assign those tasks to others.

Time spent maintaining equipment is a good investment. Well maintained equipment is more dependable, more productive and worth more at the time of resale. This type of work is familiar to all farmers but is often neglected. Following a SCI, completion of basic maintenance tasks are reported to be highly rewarding, both physically and mentally.

SPECIAL PRECAUTIONS

Farmers and ranchers with SCI's who are returning to work should plan their schedule carefully. Endurance and stamina will be reduced and will take time to redevelop. Careful planning of each day's activities will help reduce unnecessary tasks and increase productivity.

The risks associated with agricultural production are considerable and should be foremost in the mind of the farmer or rancher with a SCI. Tasks that were once performed as "second nature" now must be done methodically and cautiously otherwise the potential for secondary injuries increases. There have been numerous reports of helpers and bystanders being injured or involved in "close calls" due to the efforts of the disabled individual to complete a hazardous task. In some cases children and inexperienced family members are called upon to operate equipment or complete other jobs beyond their capability. No job associated with a farm operation is so important that it justifies exposure to unnecessary risks.

SUMMARY

Experience gained through the activities of the Breaking New Ground Resource Center clearly suggests that it is possible to successfully modify a farm or ranch operation to accommodate the desire of an individual with a SCI to continue farming. Successful case histories can be documented involving individuals operating dairy, beef, cash grain, hay, vegetable, poultry and hog farms. This includes both paraplegics and quadraplegics. It is also clear that most of these farmers have yet to realize the tremendous benefits that are possible through the application of recent rehabilitation technology to their work site. There is no reason that as more is done to improve the accessibility of agriculture to those with physical handicaps, the need to leave the farm will become influenced more by choice than necessity.

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WORKSITE MODIFICATIONS FOR FARMERS WITH BACK INJURIES

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INTRODUCTION:

According to the studies conducted by Dr. Stover Snook, Director of Ergonomics Research, Harvard University, 80% of the general population will suffer a disabling lower spinal disorder at one or more times during their career. It is also estimated that the probability of re-occurrence is four times greater after the first episode of acute disabling lower spinal disorder. (Sweere, 1983) Tompkins (1973) found that 29% of the farm operators in Vermont indicated that they were suffering from back trouble. (Field and Tormoehlen, 1982) A survey of disabled migrant and seasonal farm workers reveal that 37% reported severe backaches. (Cortes, 1974)

Causes of back injuries among agricultural producers, can be a result of heavy lifting; repetative lifting, twisting, bending, and reaching when completing farm tasks; and extensive vibration that occurs when operating agricultural machinery. There is speculation that certain types of vibration can cause permanent damage to structure of the spine. (Anderson, 1981) Poor posture, muscle activity or non activity, and fatigue have been additional contributing factors to low back injuries among agricultural producers. (Sweere, 1983)

The majority of agricultural workers, are not covered by any wage loss insurance. Therefore, the desire to return to farming as soon as possible is critical. Education in muscle strengthening exercises, lifting techniques, proper posture, and agricultural worksite modifications can be very effective in returning to farming with a back injury.

The purpose of this paper will focus on types of agricultural worksite modifications that make farm tasks easier to perform and assists in preventing further back injuries.

TRACTOR MODIFICATIONS:

Farmers have frequently complained about tractor seating related to back pain. This has resulted in many manufactures utilizing human factor engineering in seat design. These designs include independent suspension which absorbs continuous shock and vibration; adjustable lumbar support; and adjustable arm rests. Most tractors manufactured today install these types of seats. It is also possible that these seats could be installed in older machinery.

Human factors are also considered when designing operator controls in tractors. However, in older equipment, many controls may be positioned in awkward places that result in continuous twisting or excessive fatigue to activate controls. Controls can be modified using lever relocations or lever extensions which provide easy access to control activation.

Additional hand holds and steps can assist in mounting and dismounting the tractor safely with less physical strain. Depending upon the severity of the back injury, a platform or chair lift might be considered.

Adjustable steering columns, swivel seats, convexed rear view mirrors and automatic hitching devices are a few of the tractor accessories available that can benefit someone with a back injury.

BACK SAVING SOLUTIONS:

There are several devices that are available to farmers that might reduce stress on the back. The following are a few of the most commonly used devices for specific functional limitations.

Bending Restrictions

The **Garden Scoot** is used to alleviate repetitive bending when performing tasks which are eighteen to twenty four inches from the ground. This device comes in two wheels and three wheels which allows one to use their feet in maneuvering around the task. The **Back Aid**, manufactured in Australia, supports the upper body weight when performing tasks that require bending over for long periods of time.

The chest strap is attached to a spring which is mounted to an overhead support structure. An **Elevating Platform** could also be used to raise an object from the floor to the appropriate work height.

Modifications to livestock handling facilities might be considered. **Milking Parlors** eliminate the need of bending over to attaching milking equipment to the cow. **Raised Decks** installed in farrowing houses reduces the amount of bending required.

Bending And Lifting Restrictions

The **Scoop - Eeze** is a shovel which has an additional handle to help distribute the weight of the material being scooped. This additional handle also reduces the amount of bending required. Baling hay, using conventional square bales, has traditionally been a problem for someone with a back injury. Machinery such as **Round Balers** or **Bale Stackers**, eliminate the need for any manual handling of hay.

Lifting Restrictions

Sav-Y'R Back is a device that allows you to lift heavy objects with a minimal amount of effort. Using this device loads of up to 400 lbs can be moved with minimal effort. An **Overhead Hoist** or **Block and Tackle** can be used to lift heavy objects off the floor. Hoists mounted in the bed of a pickup truck can also be used for loading and unloading of heavy objects.

Carrying Restrictions

Two Wheel Dollies and **Carts** can be used for moving heavy objects such as boxes, bags of feed or seed, and calves. **Golf Carts** and **All Terrain Vehicles** with a bed or a trailer are also used for this purpose.

Climbing Restrictions

Automatic Gate Openers reduces the need to climb in and out of the tractor when opening gates. **Bin Lid Openers** allows a farmer to open or close the bin lid from the ground. **Stairs** can be mounted around the outside of the bin. This makes climbing up and down the bin easier and safer.

ALTERNATIVE TECHNIQUES:

Alternative techniques should be explored when labor saving devices are not available or modifications are too costly.

Items in the tool shed or machine shed should be placed on shelves at waist height. This will prevent excessive bending, lifting, and reaching.

Job restructuring activities might also be considered. Co-workers or family members could assist with those tasks that are more physically demanding. In turn, the farmer with the back injury, could perform the less physical demanding yet time consuming tasks.

When operating the tractor or combine, it is recommended that the operator takes frequent breaks, getting off of the equipment and stretching.

CONCLUSION:

The above ideas are only some of the many approaches that might be considered in agricultural worksite modifications. It is important that physical conditioning, and proper lifting techniques be used in conjunction with these modifications.

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EVALUATION TECHNIQUES FOR MODIFIED AGRICULTURAL MACHINES

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ABSTRACT

In 1986, the authors conducted a study for the National Institute of Handicapped Research to evaluate modifications made to self-propelled agricultural machines intended for use by operators with physical handicaps. An evaluation technique was developed and used on 29 self-propelled agricultural machines that were modified for use by disabled operators. This paper specifically discusses the evaluation process.

INTRODUCTION

Agricultural production has the highest disabling injury rate of any occupation in the United States. It is estimated by the National Safety Council that in 1986, 170,000 farm and ranch related injuries were reported of which at least 3400 resulted in permanent disabilities. In addition to work-related disabling injuries, farmers and ranchers also experience permanent disabilities from motor vehicle accidents, recreational activities, accidents in the home, and diseases such as arthritis and stroke. The Breaking New Ground Resource Center at Purdue University, established in 1979 to assist farmers and ranchers with physical disabilities, estimates that approximately 560,000 American farmers, ranchers, and agricultural workers are hindered in the completion of essential work-related tasks due to a variety of physical handicaps.

One of the most serious vocational barriers that this population must cope with is the operation of agricultural machines essential to most phases of agricultural production. Accessibility to the operator's station and the operation of machine controls are the two main areas where modifications are needed to remove this barrier. A wide variety of predominately homemade and semi-commercially available modifications have been designed, fabricated, and put in use on the more frequently used machines, such as tractors and combines. However, designers and builders of these modifications have seldomly documented their work resulting in the need to repeat the process with each newly modified machine. Currently few plans or guidelines are available to assist in the completion of these modifications. Consequently, in 1986 the authors conducted a study sponsored by the National Institute of Handicapped Research (Grant No. G008535172) to evaluate modifications made to self-propelled agricultural machines and disseminate the findings to farmers and ranchers with physical handicaps, and rural rehabilitation professionals. The focus of this paper will be on the evaluation methodology.

EVALUATION METHODS

The Breaking New Ground Resource Center has assembled an extensive collection of information on work-site modifications to make agricultural operations more accessible to individuals with physical disabilities. Many of these ideas relate to the access and operation of agricultural machines including devices such as manlifts and control modifications. Twenty-nine modified agricultural machines which featured a manlift were selected from those which have been identified and which represented the diversity of techniques being used to enable a disabled operator to use the machine.

A standardized evaluation form was developed to record data concerning each machine along with information about the individual using the machine. The specific areas addressed by the form included:

I. Background Information on the Disabled Farmer/Rancher
II. Description of Farm/Ranch Operation
    A. Crops and Animals Raised on the Farm/Ranch
    B. Terrain (rough, hilly, etc.)
    C. Building Modifications Made or Needed
    D. Type of Equipment Used on the Farm/Ranch
    E. Equipment Modifications Needed
    F. Modifications Farmer/Rancher Has Made
III. Evaluation Process
    A. Evaluation of Modifications
        1. Manlifts
            a. Mounting Frame
            b. Lift Mechanism and Moving Parts
            c. Lift Seat or Platform
            d. Lift Power and Drive Units
            e. Lift Controls
            f. Mounting and Dismounting Procedure
                1. Description of Entire Process
                2. Movements, Switches, Levers and Knobs Used
                3. Use of Accessories
        2. Controls
            a. Control Mounting
            b. Control Operation
        3. Accessories
            a. Accessory Mounting
            b. Accessory Function
    B. Evaluation Criteria
        1. Appearance of Modification
        2. Alterations to Original Components
        3. Materials Used in Construction
        4. Quality of Construction
        5. Special Features of Modifications
        6. Safety and Ergonomics of Modifications
        7. Feasibility and Adaptability of Modifications
        8. Compatibility with Able-bodied Operators
        9. Cost of Construction

The form was completed during each evaluation process. The evaluations were documented through the use of photographs, slides, videotapes, drawings, and written descriptions.

RESULTS

Four different techniques were used to transfer the operator from the ground to the operator's station. These were: powered chairlifts; platform lifts with the operator standing (Figure 1), sitting, or in a wheelchair; sling lift; and a tractor designed to carry the operator in his wheelchair. Tractor mounted lifts represented 24 of the 29 machines evaluated. The most common type of lifts were 13 chairlifts, and 10 platform lifts operated in a standing position. Control modifications were mounted on 25 of the 29 machines with the most common being modifications to the clutch and the brake.

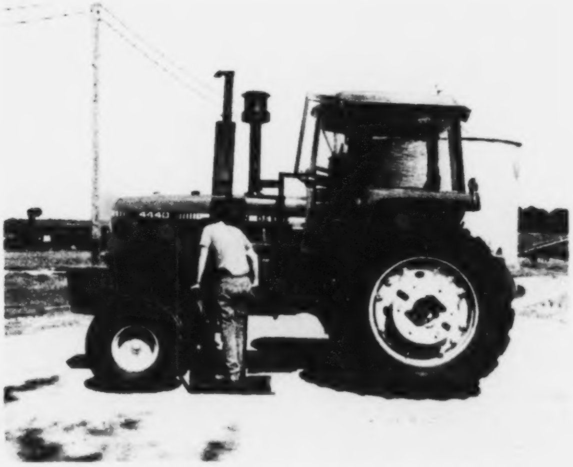

Figure 1. Platform Lift Mounted on a John Deere 440 Tractor

Regardless of how essential an agricultural machine is to a farm, any modifications must be designed and constructed to insure the health and safety of the operator. Several major safety and ergonomic problems observed during the evaluation process included: modification caused restricted access to the machine for able-bodied operators; manlift control switches not located within reach of an individual in a wheelchair; use of electric winches that utilize a cable to lift the operators, a practice not recommended by most manufacturers of these devices warn; lack of protective railings on platform lifts; and protective devices (armrests, seat belts, footrests) on chairlifts, and the presence of pinch points. In addition, many clutch and brake modifications were designed such that they were impossible or difficult to remove which presented an interference to an able-bodied operator when he or she used the machine.

To provide a resource of functional concepts the description of the overall evaluations were assembled and published by the authors for use by designers and builders of these modifications, farmers/ranchers, and rehabilitation professionals.

SUMMARY

The resources needed to modify agricultural equipment is substantial enough to justify the careful evaluation of the various alternatives prior to implementation. The prior lack of an evaluation methodology for modified agricultural equipment has led to wasted time, many unsafe and undependable designs, operator discomfort and, in some cases, abandonment of the device or aid. Most of the modifications evaluated were homemade by farmers/ranchers who had few plans, standards, guidelines, or documented experiences to use when designing necessary modifications. However, the majority of the designs completed the desired tasks and satisfied the users' needs. A future goal of the Breaking New Ground Resource Center will be to continue evaluating new approaches to improving accessibility to agricultural worksites and tasks to insure the availability of appropriate rehabilitation technology.

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Robotics
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AN INEXPENSIVE BEDSIDE/CHAIRSIDE CARE UNIT FOR QUADRIPLEGICS

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Charles J. Laenger Kaiser Rehabilitation Center Tulsa, Oklahoma

INTRODUCTION

In January 1987 an informal collaboration was begun between the two authors to define and evaluate feasibility and utilitiy of a prototype bedside/chairside robotic aid for quadriplegics. Emphasis was placed on overall cost/benefit considerations. If the cost of such robotic aids is well beyond the resources available to the severely disabled community, then a "market" of sufficient size to encourage high volume production will not materialize.

Based on these considerations, and the fact that severely disabled individuals will always require some attendant care, a robotic aid that would provide only the most essential functions was envisioned. Functions involving very high-cost technology were removed from consideration. The objective is to create a reliable unit of demonstrated benefit with a selling price which will make it available to a major share of the disabled population.

RESULTS - PROTOTYPE

Figure 1 is a photo of an early prototype of the Integrated Bedside/Chairside Care Unit (the Bedside Care Unit, or BCU) which shows the general configuration of the unit. The "tabletop" is a box-like enclosure about nine inches in depth. This is supported on a castered carriage with a height adjustment. A five-axis robot arm is mounted on one corner of the tabletop with a video display unit on the diagonally opposite corner. Arm electronics, power supplies, and a microcomputer are housed inside enclosure. Several beverage serving units are visible on the tabletop. When all beverage and food serving units are in place, 8 to 12 individual items will normally be present on the tabletop. These may be "fetched" and "recovered" by the manipulator arm at the command of the user. Hot and cold beverages, solid food, and a bookholder with page-turner are included along with personal grooming aids. Non-robotic aids may include environmental controls, television controls, and a speaker-phone with autodialing. Almost all robot-related tasks will be programmed and selected from menus presented on the video display unit.

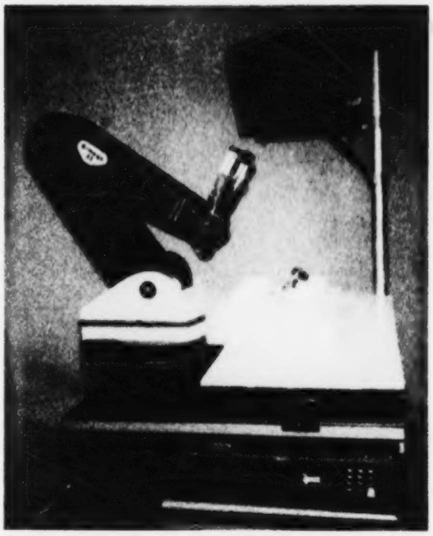

Figure 1.
Initial Prototype of the
Integrated Bedside/Chairside
Care Unit

Both "puff and sip" and voice recognition will be offered as optional means for user communication with the Bedside Care Unit.

DISCUSSION/BENEFITS

The benefits to the user which are central to the goals of the Bedside Care Unit, are very similar to those articulated by others working in the field (1). Specifically, these are services which increase the independence of the handicapped user and thereby offer the economic benefit of a significant reduction in attendant care and enhancement of employability.

COST REDUCTION STRATEGIES

A major area of cost reduction stems from the use of a low-cost manipulator arm developed by Micro-Mega, Inc. To further minimize cost, complex and expensive technologies such as mobile vehicles and wireless communication links were ruled out. In the BCU application it is assumed that food and beverages will be placed in special containers at known positions on the BCU tabletop where provision for keeping them hot or cold will be provided. Prepositioning of food items permits the BCU system to retain control of the geometry of the BCU-user relationship. Figure 2 illustrates the delivery position of a beverage container. The user, or the BCU, need only be placed so that the straw is correctly placed, and all subsequent services will be properly delivered.

PLANNED CLINICAL TESTS

A working prototype of the Bedside Care Unit is now in use and two advanced prototypes are under construction. Under a formal agreement with the Kaiser Rehabilitation Center, the two advanced prototypes will be used in a series of clinical tests beginning in April 1988.

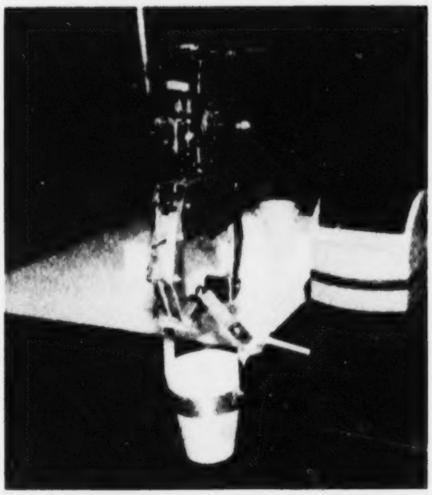

Figure 2
Delivery Position for Beverage Container

CONCLUSION

By using a low cost manipulator and achieving control of the BCU-user geometry, many of the essential needs of the user can be met, and major cost reductions realized by comparison with a system using an industrial robot arm and a mobile manipulator.

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CLINICAL EVALUATION OF A DESKTOP ROBOTIC AID FOR SEVERELY PHYSICALLY DISABLED INDIVIDUALS

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INTRODUCTION

At the Palo Alto VA Rehabilitation Research and Development Center, a third generation desktop robotic aid has been developed to perform activities of daily living (ADL's) for the severely physically disabled. This robotics technology has the potential to significantly decrease attendant and health care costs, and to give thousands of severely disabled individuals control and independence in performing daily and vocational activities.

With individuals from the Spinal Cord Injury Center, the robotic system is being evaluated to determine disabled users' reactions to robotics technology and to rate the system's reliability and quality of performance. To date, 20 severely disabled individuals have used the robot to perform activities of daily living (ADL's), including meal preparation, feeding, grooming and hygiene tasks. The robotic workstation is rated in terms of the disabled user's subjective satisfaction and a trained observer's objective rating of the robot's performance of tasks. Overall, the results from these evaluations have been positive. Feedback has been used to improve the robotic workstation, so it is now ready to be used and evaluated in home and vocational settings.

METHODS

The third generation robotic system being evaluated is DeVAR: Desktop Vocational Assistant Robot. The system uses a Unimation PUMA-260 industrial robotic arm manufactured by Westinghouse. The PUMA is controlled by an IBM-PC/AT computer and operated by the user through voice commands, using a VOTAN voice recognition unit. The previous (second generation) robotic workstation used a rotating kiosk to house supplies needed for ADL's (toothbrush, shaver, utensils). Based on feedback from users on the space utilization, aesthetics, and time needed to access the supplies from the kiosk, a new workstation was developed to provide faster, more efficient task performance [1,2]. The third generation system includes: a compact tool holder replacing the kiosk, an Otto-Bock prosthetic hand in place of a custom-made gripper, and addition of a wheelchair accessible table (see Figure 1). These additions, along with extensive software modifications, have improved the aesthetics, reliability and ease of use of the DeVAR system.

To date, 20 people [19 high-level quadriplegics (neurological levels C3,C4, and C5) and 1 Guillian Barré patient] have participated in the evaluation of the DeVAR system. These individuals have no functional use of their arms or hands and are maximally dependent on an attendant to perform daily tasks. Disabled users were asked to use the robot to perform the following pre-programmed tasks:

1. Meal preparation (using refrigerator and microwave)
2. Feed with utensils (using spoon and fork)
3. Brush teeth with electric toothbrush and rinse
4. Get a drink of water or juice with straw
5. Wash and dry the face
6. Shave the face and neck with electric shaver
7. Retrieve a mouthstick for typing, turning pages, etc.
8. Operate environmental control unit (lights, radio, phone)

All these tasks are initiated with one or two word voice commands. Each task is interactive, letting the person customize control positions. For example, tasks can be stopped at any time, with the robot cleaning up after itself as required.

Robot performance was measured by the following methods: subjective user satisfaction was measured by pre-test and post-test computerized questionnaires; a trained observer objectively rated the robot's performance (task completion, accuracy, safety, etc.); and a computerized history list recorded task completion time, commands given, and robot status throughout each session.

RESULTS

Data from the evaluations of the 20 severely physically disabled individuals were compiled and analyzed. Users rated the robot positively on the following items: safety, ease of learning, overall value, sturdiness, reliability, voice recognition, aesthetics, space utilization, noise level and task completion time. Objective observer ratings and computerized history lists confirmed the reliability and consistency of the robot in performing tasks effectively and in a reasonable period of time.

Users indicated satisfaction with performance of the robot on washing the face, brushing the teeth, shaving, and soup preparation and feeding; they have indicated a preference for the robot versus the family/attendant in performing these tasks. Users responded that 80% of the family/attendants would react positively to the robot and 90% replied they would still use the robot regardless of the family's reaction. For the question, "Given what you know about a robotic aid, would you want this robot in your home?", the following results were obtained:

	PRE-TEST	POST-TEST	
YES	4/20	17/20	85%
UNDECIDED	15/20	3/20	15%
NO	1/20	0/20	0%

DISCUSSION

Results of this study are significant in that few analyses have objectively evaluated and demonstrated the practical applications of robotics technology for severely physically disabled[3].

In comparing DeVAR with prior robotic workstations, significant gains were noted in the areas of safety, time to complete tasks, reliability, aesthetics and space utilization.

The results from these clinical evaluations have demonstrated the high reliability and quality of the robot's task performance, as well as the disabled users' satisfaction with and acceptance of the DeVAR system as a viable aid in achieving independence.

CONCLUSIONS

Our experience with DeVAR over the past year shows that it is ready to be taken into home settings for on-site evaluations. In addition, due to interest from disabled users and prospective employers, a fourth generation DeVAR system, which uses a robotic assistant to provide maximal independence in a vocational setting, has been designed. The DeVAR system will be installed in community home and vocational settings within 6 to 12 months with ongoing on-site evaluations.

This robotics technology offers the opportunity for the severely physically disabled to return to productive employment. This can have tremendous impact in decreasing attendant and health care costs; increasing revenue benefits to the disabled individual, the employer, and the community; and most importantly, has the psychological benefit of giving the disabled person maximal control and independence in his/her daily life.

ACKNOWLEDGEMENTS

Special thanks to David Lees and Bob Crigler for their extensive technical work and expertise in this project.

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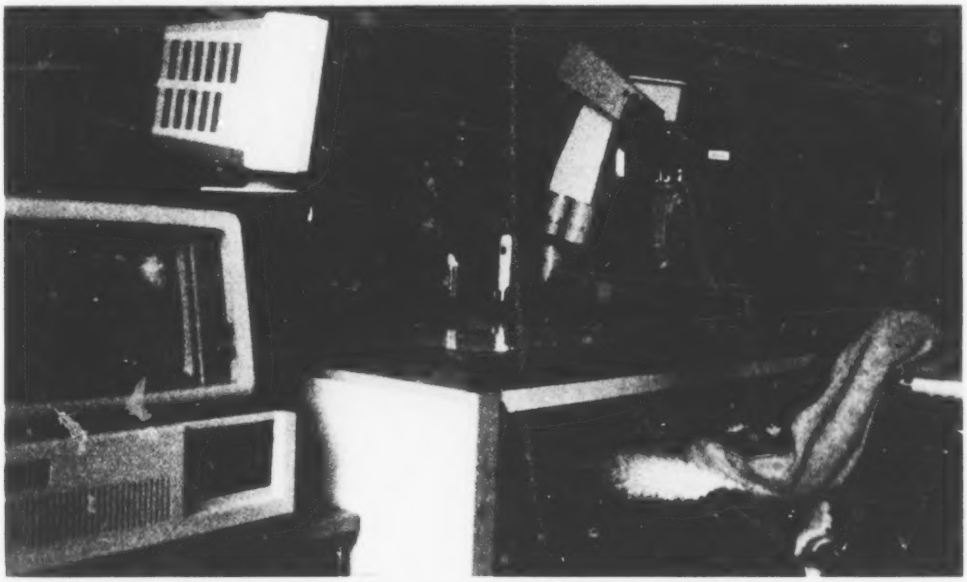

Figure 1: Disabled user evaluates the DeVAR system.

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A THIRD GENERATION DESKTOP ROBOTIC ASSISTANT FOR THE SEVERELY PHYSICALLY DISABLED

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INTRODUCTION

We have constructed a voice controlled robotic assistant for the severely physically disabled using a Unimation PUMA-260 industrial robot with an IBM-PC/AT as the high level control computer. The system is operated by voice commands and communicates to the user with both voice prompting and a color display screen. The tasks for the robot have been designed to adapt easily to different users. They include: toothbrushing, face-washing, shaving, and preparing and feeding simple meals. Turbo-Pascal was used to develop the control software for the PC/AT. The PUMA-260 controller was programmed in VAL-Plus. Both are high-level languages, designed for rapid software development and testing.

The clinical desktop robot (DeVar) is one part of a larger robotics project being undertaken at Stanford University and the Palo Alto VA Hospital. A sophisticated mobile robotic assistant is being developed at Stanford which provides a valuable source of new technology for the clinical system. This paper describes the "third generation" of DeVar, which incorporates many improvements based on the testing of previous versions of the system with disabled users.

METHODS

Design strategy

One of our main objectives in designing the third generation system was to demonstrate that DeVar is ready to move out of the laboratory and become a viable commercial product. In keeping with this desire, we have attempted to use as many commercially available parts as possible in the construction of the workstation. We have also tried to keep the design of the workstation as compact and attractive as possible.

Worktable

The DeVar worktable consists of a six by three foot office desk that has been raised approximately one foot to accommodate wheelchairs. The robot is mounted near the center of the table-top and is surrounded by a refrigerator, microwave oven and a small equipment holder (See Fig. 1). All of the items in the holder are standard unmodified household products, making them easy to replace when they wear out. Fig. 1 also depicts the new end-effector that we are using: an Otto-Bock Greiffer. It is a human hand prosthesis specifically designed for high performance manipulation tasks rather than for cosmesis. It has both a cylindrical grip, for holding large objects, a fingertip grip, for holding small objects tightly, and a small hook. In this human-scale environment, the Greiffer offers a much better price/performance tradeoff than grippers developed specifically for industrial use. It has performed extremely well in the nine months that we have been using it.

User Interface

The control interface was designed to be as transparent and flexible as possible. Its principal features are as follows:

- Task programs are designed to adapt easily to different users. For example, when eating soup, the user starts out by guiding the spoon to his mouth using voice commands. The robot stores this position and returns there for the rest of the feeding task. This makes it very easy for patients with different wheelchair heights and seating positions to use DeVar.
- To increase safety, the robot is programmed to move in small incremental steps near the user's face. The user is also queried by the system ("Are you sure?") before any task begins, to guard against misrecognitions by the voice system or spurious recognitions caused by background noise.
- The user is provided with both audio and visual feedback. All commands and prompts are spoken to the user by a Votan speech recognition and synthesis system. The last ten commands are displayed on the color monitor for reference. Finally, the user is prompted with a list of the commands available to continue with the current task or modify its execution.

New Features

New functions that we have implemented as a result of our clinical tests include:

Voice Set Switching: We have programmed the voice recognition system to "listen" for only those words which make sense in the current context. This technique has allowed a dramatic increase in recognition accuracy, and makes the system much more pleasant to use.

Message Passing to/from Robot: The robot and the user's display are each controlled by separate computers. To keep the displays properly synchronized with events happening in the outside world, the robot sends status messages to the IBM-PC/AT. Message passing is also important for controlling the voice-set switching.

History List: The control program has the ability to store a history of the user's commands, with a time stamp and information about the robot's status. This is very useful for studying the system's performance and the user's control of the robot.

Emergency Stop Switch: We have installed an emergency stop switch, which can be mounted on a wheelchair behind the user's head. This allows the user to stop the robot's motion at any time, even if voice recognition fails.

New Commands: Two new commands are available which make it much easier to retrieve small objects from the tabletop. A BSR X-10 compatible environmental control unit, along with three new voice commands, allow DeVar to be operated entirely by voice, including switching the power on and off.

Backtrack Feature: If the robot fails to pick up an object correctly, it can be commanded to reverse the path it has just followed so that the user can guide the robot to the correct location and close the hand around the object. A single command will then continue with the task that the user was trying to execute.

Timed Sequence: Both the toothbrush and shaving programs are designed to cycle past various points on the user's face, stopping for about 30 sec. at each point. This avoids the problem of making the user talk over the noise of the shaver or with a mouth full of toothpaste.

RESULTS AND DISCUSSION

From a system reliability perspective, the two most significant features of the third-generation DeVar are the vocabulary set switching and the message passing protocol. Set switching dramatically improved the quality of voice recognition and made the system much easier to use. The message passing feature allows the robot to report its progress through a task to the control program. Previous versions of the control program assumed that a task would be completed successfully once it was started. Now, if a task is interrupted in the middle, the control program is notified, which makes it much simpler to recover smoothly. The status messages also make it much more difficult for the system to become "confused": thinking that an object has successfully been moved from one place to another, when it actually was not, for example.

The other new features are important for making DeVar a useful product outside of the research laboratory. Without the project staff available to monitor the operation of the system, the user must have the ability to turn it on and off and recover from minor errors.

Results of testing the third generation DeVar over the past nine months have been very good. A questionnaire given to the severely disabled users who tested the system showed that a large majority would like one in their home if it were available (1).

CONCLUSIONS

Our experience with the third generation DeVar indicates that it has become a very reliable, functional system which is ready for daily operation by disabled users. We are presently programming the system to perform vocational tasks, and plan to place it outside our laboratory in an office setting in the near future. This will give us valuable information on the performance of DeVar in everyday use.

ACKNOWLEDGEMENTS

The authors would like to thank Joy Hammel and Karyl Hall for their help in carrying out the clinical evaluation of DeVar. We are also grateful to Jeff Aldrich, Jim Anderson and Stan Hanel for their efforts in the design and construction of the DeVar worktable.

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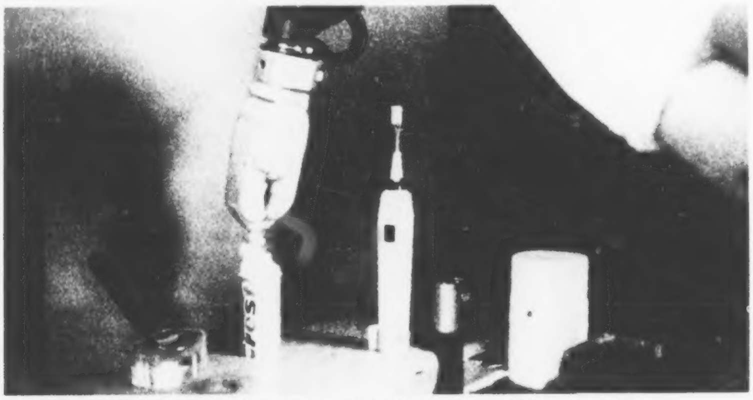

Figure 1: DeVar Equipment Holder

USE OF ROBOTIC ARM AS A REHABILITATION EXERCISE PARTNER: A THERAPEUTIC ENHANCEMENT

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The ultimate goal of our system is to be a partner in the therapeutic process. A partner which is cost effective, relieves the therapist of performing the fundamental exercise routines, collects patient exercise performance data, and generates quantitative performance reports. The most frequently used approaches to muscle re-education for stroke victim patients are Bobath, Rood, Brunnstrum, and Proprioceptive Neuromuscular Facilitation. Using these techniques, a typical therapy session involves the therapist repeatedly moving the paralyzed arm through a variety of predetermined patterns, e.g. from the patient's lap to her shoulder, from the floor to the patient's chest. The patient may also be required to use her good arm to move the paralyzed one through these same pattern movements. The patient is often required to reach and touch an object, held at a variety of points in space [1]. Our robotic arm system was designed to act as an assistant to the therapist, i.e. as a "smart exercise partner" which performs these exercise routines with the patient, collects patient performance data, and generates reports.

SYSTEM DEVELOPMENT

The first issue concerned the design and development of the software and hardware by interdisciplinary team members. The technical requirements were designed to satisfy the therapists' requirements. Once the technical aspects were implemented, we conducted a field trial using only the therapists. Based on their feedback, we made system modifications and delivered the modified system for a clinical field trial.

During the field trial we want to determine if the system will enhance the therapeutic process by having the robot arm perform these exercise routines with the patient, thereby freeing the therapist to conduct activities which require direct attention. Important issues we are addressing in developing and testing such a system are: therapist evaluation of the system in terms of usefulness as a therapeutic tool, therapist acceptance of the technology, patient perception of the system as a therapeutic tool, and patient acceptance of the technology.

The study's subjects are Cerebral Vascular Accident (CVA) patients. The subjects, numbering about 50, are adult recovering stroke victims, both right and left hemiplegics. The patients are volunteers under the care of one of the 13 registered occupational therapists participating in the study.

We are using the UMI RTX robot arm. This particular robot is designed to be controlled from an IBM compatible personal computer and has many features which make it safe to use with patients. The robot has six degrees of freedom: 1) (vertical) column, 2) shoulder, 3) upper arm, 4) lower arm, 5) wrist unit, 6) gripper [2].

In order to monitor the the patient's movement we used two touch switches, one in a home position and one on the robot's gripper. These are basic plate switches with a control signal light added. The data acquisition board, designed by one of our electrical engineers, is the system component which collects the switch sensor information. In order to design a system that meets the users' needs it is imperative to establish a research team which is comprised of the end users and the designers [3]. With this in mind, we formed a team consisting of occupational therapists (one group of end users), a biomedical engineer, robot technology consultants, electrical engineers, and computer programmers.

Through discussions and demonstrations the therapists "designed" the system in terms of explaining the exercise routines, screen formats, and report styles they desired. The technical team members "designed" the system in terms of designing the data acquisition board, modifying the basic touch switches, programming the robot to perform these exercise routines, and writing the computer program to generate the screen formats and the reports.

Once the system requirements were developed, the system was delivered to the Rehabilitation Institute of Detroit for a pilot field trial. The therapists were given a training session on how to use the system. At this time the therapists were instructed to use a logbook to record their usage time and comments regarding the system. During this three week trial period, the therapists used the system by acting as patients and performing the exercise routines. Suggestions and comments regarding the system were collected and discussed. Modifications which were necessary were implemented during a system modification period.

The clinical field trial is currently being conducted at the Rehabilitation Institute of Detroit. The therapists were introduced to the modified system during a training session. The therapists are using the system with their patients in conjunction with traditional therapy. A typical session involves the therapist entering patient information into the computer, e.g. name, ID number, and recovery stage, followed by observing the patient perform the exercise routines, and discussing with the patient the results of the report.

The exercise pattern movements were designed by the therapists, i.e. the therapists chose the points in space where the robot arm should move to. The therapists selected a variety of points in space which require the patients to reach low, high, midline, and to the right and left. The pattern movements vary in respect to level of ease, i.e. some of the robot arm's positions in space are easier to reach than others. This variance allows for patients at the different recovery stages to use the system.

In a typical exercise routine, the patient is seated in her wheelchair facing the robot. The home switch light goes on indicating that the patient should touch it (the home switch is usually placed on a step stool located at the patient's side). The arm moves to its first point. The gripper switch light mounted on the robot arm goes on for a predetermined amount of time. The patient should reach and touch the gripper switch before the light goes off. When the time delay is up, the gripper switch light goes off and the home switch light goes on. The patient should then touch the home switch. The arm will move to another point in space at which time the gripper switch light goes on. The patient should reach and touch the gripper switch. This process will be repeated until the pattern is completed. The data acquisition board collects the switch sensor information which is stored in the patient's performance record, i.e. the "hits" and "misses" (successful and unsuccessful attempts to touch the home and gripper switches at the appropriate time). The report indicates the number of hits and misses and at which points in space these occur.

At the end of the patient's initial session, she is assisted in completing an evaluation form. After the patient's final session she will again complete an evaluation form. We will compare the responses of the two sets of forms. The therapists will complete a questionnaire and some of the therapists and patients will be interviewed at the end of the clinical trial. We will also examine the therapists' log book, in which they are recording comments, suggestions and system problems.

RESULTS

The system was evaluated during the pilot field trial by the therapists, who recorded their comments in a log book. They expressed enthusiasm and felt the system would be a useful therapeutic tool. Preliminary clinical trial results obtained from the patient evaluation forms suggest that they like the system. The patients have expressed that the system is helpful as a treatment tool, safe, and interesting to use.

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PRELIMINARY CLINICAL EVALUATIONS OF A PROTOTYPE INTERACTIVE ROBOTIC DEVICE (IRD-1)

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INTRODUCTION

Children with severe physical impairments are constrained to grow and develop in an environment over which they have little or no control. Much of a child's basic cognitive development has its basis in the child's active interaction with and manipulation of the physical environment. Among normally developing children, the manipulation of objects plays a key role in the development of cognition, progressing from simple exploratory actions, to actions permitting vigorous exploration of the properties of objects, to complex coordinated chains of actions performed upon a set of objects. For children with severe physical impairments, only very rudimentary forms of the earliest of these classes of actions may be available. Thus, there is a critical need to provide these children with a means of producing a variety of actions over which they have independent control.

To date, the major technological solution to the cognitive and adaptive needs of young children with severe physical handicaps who may also exhibit significant intellectual delays has been the use of microswitches to permit response-contingent activation of battery-powered toys, tape recorders, vibrators, etc. (4,5). Response-contingent stimulation in turn has been used for the improvement of motor functioning, e.g., head control (2). The use of response-contingent stimulation provides, however, only the most primitive of cognitive challenges.

The use of robotic devices, especially small robotic manipulator arms, by these severely physically handicapped children does present a possible avenue by which the desired active exploration and manipulation of objects can take place (1). Young physically handicapped children must be provided with a means to explore objects through simple manipulative actions, to manipulate objects in a fashion consistent with the properties of the object, and to coordinate actions into more complex sequences in response to constant or changing environmental demands.

Purpose

The purpose of this project was to conduct an initial clinical evaluation of a prototype Interactive Robotic Device (IRD) which has been described elsewhere in detail in these proceedings (See "Development of a prototype interactive robotic device for use by multiply handicapped children"). This evaluation was designed to determine the feasibility and applicability of the use of IRD systems in general and the prototype system in particular by young children who exhibit severe physical impairments and who have either intellectual delays or severe cognitive impairments. Table 1 describes the manipulative classes that have been included at each of the two levels of implementation of the IRD prototype. Exploration permits visual examination of an object while simple undifferentiated actions may be applied to any object. Differentiated actions are specific to the properties of the object being manipulated.

METHOD

Subjects

Four preschool-aged children, ranging in age from 2 to 4 years, and five elementary-aged children, ranging in age from 5 to 9 years, participated. All children exhibited moderate to severe physical impairments. In addition, five of the nine children had significant intellectual impairment or delay.

Procedure

Each child participated in 2-3 sessions with the IRD device with an adult present throughout. The adult initially showed the toys to the child, demonstrated how they could be activated, then returned the toys to the toy rack. The adult then demonstrated how to touch the pictures of the toys on the membrane keyboard to cause the IRD to get the toy from the toy rack and how to touch the action squares to cause the IRD to produce or repeat an action. From that point, the adult served only to assist the child with access to the membrane keyboard, or, with the more severely intellectually impaired children, to prompt them to redirect attention to the pictures on the keyboard or to continue responding.

For these sessions the IRD was programmed to respond at Level 1.2, that is, to respond to the first touch on the membrane keyboard by selecting one of three toys and to the second touch by performing one of three actions specific to that toy. Upon completion of an action routine, the IRD held the toy for a designated period of time during which the child could cause the same action to continue by touching the same action square or could select a new action by touching one of the other action squares. Failure by the child to make any response caused the IRD to return the toy to the rack and assume a "ready" position.

RESULTS

Observational notes revealed that all the preschool-aged children were attentive to the IRD when active and that two of the four appeared to develop toy preferences. Among the elementary-aged group, which included several significantly intellectually impaired children, visual attention was not as great, although behavioral indices of interest in the auditory events were noted. Two of the five children did demonstrate independent cause-and-effect responding. Performance monitor data for the preschool children revealed from 7 to 32 discrete toy selections and from 4 to 27 selections of action routines within sessions ranging from 4 to 17 minutes in length.

DISCUSSION

These initial results indicate that the continued use of the IRD system by young children having severe physical handicaps and varying degrees of intellectual delay or handicap is warranted. It should be noted that these preliminary findings are the first of their using a robotic device designed exclusively to match the cognitive functioning and needs of chronologically or intellectually young children with significant physical handicaps. Some of the children acquired an understanding of the use of the system to select toys and control their manipulation within the two sessions. Such children will require a system which permits more varied and complex action routines to be "constructed" by them. For several of the older children who had more serious intellectual delays, a system programmed to operate through a single switch will be needed before the multiple-choice membrane keyboard can be introduced. Finally, such a brief exposure can only answer questions concerning appropriateness and feasibility of the approach. Information concerning the usefulness of IRD systems in fostering intellectual growth will require more systematic and sustained investigations.

ACKNOWLEDGEMENTS

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Table 1. Manipulative Skills Implemented at Each Cognitive Level of the IRD System

CLASSES OF MANIPULATION	COGNITIVE LEVEL IRD Level 1.1	IRD Level 1.2
Exploratory	X	
Simple, Undifferentiated Acts	X	X
Complex, differentiated		X

DEVELOPMENT OF A PROTOTYPE INTERACTIVE ROBOTIC DEVICE FOR USE BY MULTIPLY HANDICAPPED CHILDREN

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INTRODUCTION

Among the outcomes of recent interest in the problems and needs of persons with more severe disabilities has been an increased awareness of the needs of individuals with severe or multiple impairments. Of particular concern are those individuals who possess physical impairments of such severity that their opportunities to exercise their rights to equal opportunity in education, employment and independent living have been limited. In particular, children with severe physical impairments are constrained to grow and develop in an environment over which they have little or no control. Much of cognitive development has its basis in the child's active manipulation of the physical environment. The understanding of cause and effect relationships and the motivation of a child to explore and experiment physically with his environment are just two keys to the learning process that are severely restricted as a result of the child's physical impairments. Among normally developing children, the manipulation of objects progresses from simple exploratory actions, to actions permitting vigorous exploration of the properties of objects, to complex coordinated chains of actions performed upon a set of objects. For children with severe physical impairments, only very rudimentary forms of the earliest of these classes of actions may be available. The use of small robotic manipulator arms by these severely physically handicapped children does present a possible means to facilitate active exploration and manipulation of objects.

Most applications of robotics to the needs of severely disabled individuals have been in the area of adult rehabilitation (1). For children with physical impairments, applications of robotic devices have been reported in the area of vocational training, primarily simple sorting and assembly tasks; for adolescents and young adults (2), in the area of vision sensing; in a robotic aid workstation for sorting and stacking by adolescents (3,4), and in the area of independent living skills of an adolescent boy (7). Only one attempt has been made to examine the feasibility of using a robotic manipulation device with very young normal and developmentally-delayed children under 36 months in age (5). It was demonstrated that the children could learn to continuously activate a switch to complete a useful movement and that interest was greater when the robot performed a useful task rather than a series of movements.

In order to provide the necessary manipulative abilities that meet the cognitive needs of children with severe physical impairments and intellectual delays a robotic device system is needed that, at minimum, will enable training to occur at two successive levels of development. At the first level, the system must be capable of providing the child with a means of using simple actions to repeat or prolong an interesting stimulus or event produced with an object. At the second level, the robotic system must allow the child to control component actions and to interact in the process of coordinating these actions into more complex sequences. Because such training is part of the educational program for the child, the system should also permit a teacher to periodically call forth data concerning the child's performance and progress. The research to date represents initial activities aimed at examining the feasibility of implementing such a system with commercially available computers, interfaces and small educational robot arms.

METHOD

The first level of the interactive robotic device (IRD) was divided further into two sublevels (6). At level 1.1, the IRD is programmed to respond to the closure of a single switch by performing a randomly selected action on a sequence of toys. At level 1.2, the IRD is programmed to respond to a two-step sequence, first responding to the closure of one of several switches by selecting a specific toy, then responding to the closure of one of several switches by performing an action upon the object specific to the properties of that object. The first sublevel demonstrates simple cause-and-effect relationships while the second step begins to differentiate the properties of objects and to associate classes of actions with certain objects.

Level 1.1 was implemented using an IBM RS-1 robot and two toys capable of producing interesting auditory and visual consequences when manipulated. Programming provided both a brief demonstration and response pause opportunities in which the student could initiate or maintain control in order to repeat the object manipulation. Data collected and printed included initial and response pause actuations, and interresponse times and average interresponse time for the child. Though selected for its programming language and realtime monitoring capabilities, the RS-1 served mainly for initial feasibility studies due to its lack of portability, and noise levels arising from its hydraulic components that mask auditory effects from toys.

Implementation of Level 1.2 used a five degree-of-freedom Mitsubishi Movemaster robot and controller, a Compaq portable computer, a Seraid hardware/software interface (keyboard emulator), and a Unicorn membrane keyboard. Three toys (tennis ball can filled with small ball bearings and encircled with metal "sleigh" bells, a plastic slinky, a "Nerd Honker" bicycle horn) were modified by adding jigs and fixtures to permit manipulation and placement by the robot on a toy-rack when not in use. An interaction session begins with the IRD performing a "ready ritual", the IRD responds to the child touching one of three large drawings (13 cm x 13.5 cm) of the toys on the membrane keyboard by picking up a toy and moving it to a "home" position and performing a "pause ritual". If the child touches one of three "action squares" (13 cm x 6 cm) located below the object drawings, then one of three routines is performed that have been programmed for that particular toy. If no response occurs the toy is returned to the rack and a ritual is performed. At the conclusion of each action routine, the IRD performs a pause ritual to indicate readiness to proceed. Data collection programming permits information concerning toy selections, actions selected for each toy, number of actuations per toy selection, and interresponse intervals to be gathered, stored on disk, and printed upon request for each child interacting with the device.

RESULTS AND DISCUSSION

The hardware seemed to meet most of the needs as far as being able to respond to student input via multiple-choice arrays, control the robot, and document the results. However, limitations were encountered having an impact upon future investigations and development in this area. Use of a commercial serial interface/keyboard emulator (the Seraid) does not permit timing of a switch closure required to program a minimum delay in order to eliminate accidental or uncontrolled switch closures by a child. A parallel interface would facilitate development of this feature. The speed, acceleration and deceleration characteristics of the Movemaster robot limit some desired sound and visual effects. Future improvements might involve the addition of a programmable sound generator which could produce sound effects in synchrony with object movements. Use of any robot would not be recommended if the child were physically able to enter its working envelope. In order to permit safe physical interaction between the IRD and the child that is needed within more complex object manipulation sequences, a robot will have to be selected or developed with better compliance and collision avoidance characteristics, and perhaps with a proximity-to-user sensing for safety.

These initial activities, including a preliminary field evaluation with handicapped children, did suggest that further investigation of Interactive Robotic Device (IRD) system is feasible and warranted. One prominent feature currently being addressed is an artificial intelligence component to carry out on-going performance monitoring, to interpret data, and generate automatically information concerning student' progress.

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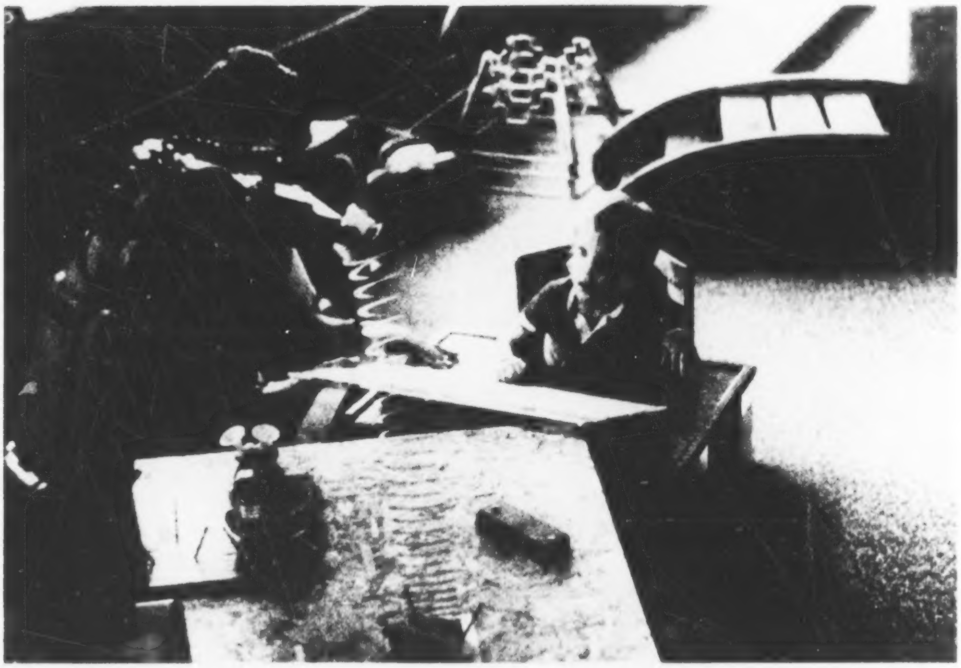

Fig. 1 S.W. (age 5, Cerebral Palsy) interacting with the IRD-1, which is "playing" under S.W.'s directions with slinky-toy. The toy-rack is seen below the moving arm.

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THE MANUS WHEELCHAIR-MOUNTED MANIPULATOR: DEVELOPMENTS TOWARDS A PRODUCT MODEL.

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Introduction

The objective of the Dutch MANUS Project is the development of a reasonably prized wheelchair-mounted manipulator with a modular computer-assisted control structure, as has been reported at the RESNA meetings of 1986 (1) and 1987 (2). Technological developments are realized in a close collaboration between the three institutes represented by the authors to achieve a high degree of integration of all system aspects (mechanics, electronics, computer hardware and software), in a trade-off between functional requirements and constraints on production costs.

The combination electric wheelchair and manipulator offers a functional compensation for the impairment of both mobility and upper limb functions. Individually selectable controls and reconfigurable microcomputer-assisted procedures are used to control both gripper and wheelchair movements in a unified way. Since the manipulator is mounted on the wheelchair, it is first of all intended to operate in an unstructured human environment of which it has little or no knowledge. Therefore much emphasis is placed on interactive procedures in which the user directly controls gripper (endpoint) movements and wheelchair displacements. In addition, a limited number of preprogramming and replay features will be offered to speed up or facilitate certain tasks. However, these computer-controlled movements will always proceed under close supervision of the operator, who at any moment will be able to influence the course of its execution or stop the movement.

New developments

Since last year's report, most efforts have been concentrated on the development of a product model, elaborating on the experience gained from the technical evaluation of the first experimental model. The evaluation showed that no basic changes were necessary in the concept, and indicated where continuing design efforts would be most effective in order to meet the design objectives of functionality, safety, cosmetics, production costs, life expectancy, and reliability. Whereas in the initial phases of the design most efforts were directed towards the more user-oriented aspects, in the present period extensive re-design efforts have been invested in the elaboration of those aspects necessary to make the system evolve into a consumer product. This has included rather extensive changes in the details of the design, increasing functionality and reliability where necessary, but simplifying it where possible, with special emphasis on the use of cost-effective production techniques. Some of the highlights of the new design with respect to the one reported in (2) are:

* A new cosmetical design for the manipulator, featuring more rounded shapes, integrated with aluminum casting structural elements of the segments of the arm.
* A newly designed two-fingered gripper with adaptive elements to assure a firm multi-point grip of objects with various shapes.
* A 5 kg weight reduction has been obtained by the use of carbon fiber elements for the telescoping vertical base elements. This brings the wheight of the detachable manipulator unit to about 15 kg.
* A simplified and more reliable gas spring weight compensation system for the segments of the arm has been realized.
* A wheelchair mounting kit is under development to adapt the system both mechanically and electrically to different types of electrical wheelchairs.
* A headrest control unit is under development, which can be used to control both manipulator and wheelchair movements, while maintaining a support for the head.
* A serial communication system has been developed to link different subsystems through a two-wire connection. The original firmware design has been implemented in EPLD's and PAL's for the master and a proprietary gate array circuit for the slaves. This substantially reduces the problem of connecting subsystems through moving joints in tight spaces, simplifies external connections between the removable mechanical arm unit and the control box fixed on the wheelchair, and provides an electrically isolated link with controls, wheelchair electronics, and external devices.
* A compact system for absolute joint angle measurement has been developed, using a two-track serially-encoded disk. An additional incremental encoder is used for interpolation and servo control.

- A servo control system has been developed which includes a coordinate transformer within the loop for wrist position coordinates. It also includes vector velocity and gripper orientation control algorithms to maintain both movement direction and gripper orientation, even outside the linear operating range. This compensates for nonlinear effects from limited ranges of motor torques and velocities. In the same way, it is used to limit vector velocities (while maintaining the direction of the movement), which may be individually specified in each user configuration.
- Much attention has been paid to user safety, both in the mechanical design and in electronics and software. Thus, slip couplings of an improved design limit exerted torques, and an independent hardware watchdog continually checks software functioning. The software in turn checks watchdog functioning at start-up and continually checks critical communication links, servo parameters, and functional safety limits.

Three units of the prototype will be realized, one for its further development and evaluation as a rehabilitative tool, two for technical evaluation and industrial spin-off studies. The prototype system is to be shown during the conference.

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AN INTELLIGENT MOBILE PLATFORM FOR HEALTH CARE APPLICATIONS

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ABSTRACT

The field of robotics offers great potential in the health care field. Unfortunately there are still a number of problems that need to be overcome in order to develop a robotic device that will provide a starting point for the many new applications. This paper describes a new initiative just commencing at the National Research Council of Canada its goals and methodology.

INTRODUCTION

As health care costs have spiraled upward, technology has become an important means for taming these costs (1). Chronic care bed costs in particular are very high but there are many chronic health care facility users who would like to live at home with a greater degree of independence. In fact many of these people are able to live at home or in small group homes with the help of part-time nursing. There are many among the disabled and elderly population who would like the independence this sort of care offers. Unfortunately this option is only available to a few. The elderly in particular, are growing demographically and the proportion of the health care budget for care of the elderly will escalate dramatically over the next decade. Robots, because of their flexibility, offers great potential toward meeting these new health care demands. The intention of this project is to develop an autonomous robotic platform that melds current technology to develop applications for the health care field.

There are many areas in the health care field where an autonomous mobile platform may decrease costs and offer increased patient independence (2). Amoung the many potential applications (3) are: dispensing medication, physical assistance for walking and lifting, and assistance with chores. The needs of the target population itself must be assessed to develop appropriate implementations of the required robotic aids. From the start, the robotic platform must have a high degree of processing and physical power. This will provide the platform with a high degree of flexibility for the vast array of potential applications.

METHOD

In order to perform these rather complex tasks, the platform must be quite sophisticated. Work on this project will extend over several years. A number of tasks have been determined as goals for the project:

The first two years will involve developing a generic platform that safely performs a number of lower level autonomous functions. To accomplish this a number of tasks must be performed.

1. The platform must be given the ability to move from one point to another in an unknown environment, avoiding collision with obstacles.
2. Techniques must be developed for detecting the human commander or other humans.
3. The sensors and the typical environment in which the platform will operate must be modelled to facillitate sensor integration for scene recognition and map updating.
4. Investigate applications of the technology with health-care users and professionals, and equipment manufacturers.

Beyond the first two years, the platform will be refined to provide a higher level of control through a natural language interface and a speech recognition system. Applications will be refined, tested and adapted for commercial applications.

A commercially available mobile robotic platform has been purchased (Cybermation K2A). The first two year goal is heavily involved with sensor system development: both for obstacle avoidance and for human sensing. Initially the platform will be fitted with twenty-four ultrasonic sensors spaced evenly around the girth of the platform. With this arrangement simple obstacle avoidance for one class of objects can be developed. The processing power for the platform will be in the form of three 68020 computer boards (VME bus) configured for operation under the Harmony operating system. Harmony is a real-time, multi-tasking, multiprocessor operating system that has been used in the past for control of complex robot movements. Initial software development will be in the Lisp programming language. Once the system hardware and software have been sufficiently tested, the VME processors will be moved to the platform's card cage.

Separate controllers will be developed for each of the sensors and the output devices of the platform. They will communicate with the VME boards by way of a separate, parallel communication bus. The initial physical arrangement for the system will be as shown in figure 1. A separate card cage for the sensor processors will be mounted on the platform. Power and communication with the sensor/motor drive subassembly will be via power and ethernet cables.

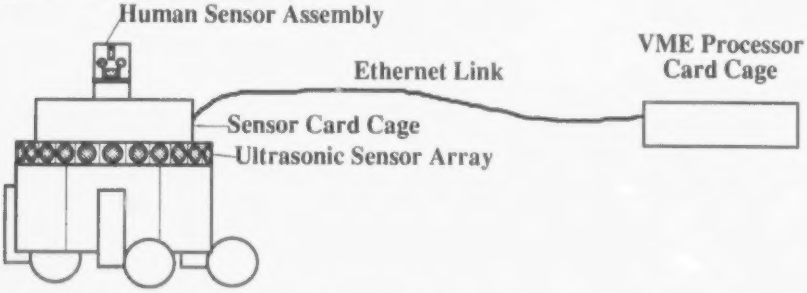

Figure 1. Initial configuration of the mobile robot platform project.

STATUS

The platform and ultrasonic sensors have been purchased. An ultrasonic sensor controller has been designed and will be fitted onto the platform.

A new ranging sensor is now under development. Using structured light, this sensor will be a fast and inexpensive way (one second for thirty rays of a ninety degree field of view) to provide scene recognition and obstacle avoidance.

ACKNOWLEDGEMENTS

The authors would like to thank the National Research Council of Canada for its support in this effort.

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THE DEVELOPMENT OF A ROBOTIC AID WITH AUTOMATIC GRASPING CAPABILITIES

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1. INTRODUCTION

Damage to the spinal cord is one of the most devastating forms of traumatic injuries that an individual can sustain. In Canada alone, every year, approximately 1000 new cases of spinal cord injury are recorded. Depending on where along the spinal cord the injury has occurred, the resulting paralysis and loss of sensation below the level of the injury often lead the individual to an existence that is totally dependent on other persons. Furthermore, with the increased life expectancy brought about by the improved medical care and treatment of these patients, it has become of fundamental importance to increase their independence, thereby hastening their return to the community. Although a variety of technological aids exist to provide environmental control, there currently are no readily available aids that allow the individual to manipulate physical objects in his/her immediate environment. Since patients with C_5 and higher quadriplegia are dependent on others partly because of their lack of prehension, it is obvious that a general purpose device that provides such an ability is necessary. Recent advances in robotics and computer technology make it very tempting to investigate the feasibility of providing such an aid to the physically disabled.

2. PROBLEM STATEMENT

When one attempts to recover lost human functions, it is often the interface between man and machine which presents the most difficulties. Normally, control of a robotic arm is achieved by direct inputs to the controller through a standard keyboard. For the handicapped, command of the arm through such a terminal, perhaps by a mouthstick, is limited and speed of control is particularly affected. Recent advances in voice recognition technology, however, offer a relatively efficient and unencumbering mode of control, especially for high level quadriplegics with no residual upper limb motion. It should be noted, however, that controlling a robot through voice recognition does present its own difficulties. In particular, early research efforts have shown that requiring the user to guide the arm through a task by issuing voice commands to directly control the movements of each joint of the robot leads to user fatigue and frustration. The fatigue and frustration result from the high degree of concentration required, especially at the fine motion level, to complete the task. It is desirable, therefore, to reduce this "control burden" by increasing the autonomy of the robotic aid. The inherent lack of structure in the robot's intended working environment, however, provides a major roadblock to the development of such an autonomous robotic aid. As a result, most research efforts to date have imposed some structural conformity by adopting a "workstation" approach: the robot is located on a worktable and all objects that it must access are precisely located within its reach. The tasks the robot can perform are then stored as pre-programmed routines. This arrangement, by necessity, limits the versatility of the robotic aid. Consequently, some research efforts have, instead, investigated the "direct control" approach where the user remotely manipulates the robot to accomplish a desired task. This strategy resulted in a high control burden being placed on the user, particularly when the user was required to make the fine motions necessary to align the gripper with an object and grasp it.

We believe that the "direct control" approach is the most promising. We realize, however, that for this method to be truly effective, the control burden placed on the user must be reduced. In particular, we believe that providing the robot with automatic grasping capabilities will significantly reduce the control burden on the user thereby increasing his/her acceptance of the system.

3. EXPERIMENTAL DESIGN: Equipment and Methods

The main thrust of the robotic aid project is to investigate the problems associated with controlling the robot, providing it with automatic grasping capabilities, and interfacing it to the user. Furthermore, we have decided to use, wherever possible, off-the-shelf equipment to illustrate the feasibility and viability of such a system for the handicapped. To this end , a commercially available arm and voice recognition unit have been obtained. The robot is the RTX Personal Robot Arm manufactured by Universal Machines Intelligence Inc.. It is a six degree-of-freedom robot that has been marketed by UMI for healthcare applications. It features a relatively long reach (68.5 cm) and a large (0.934 m^3) working envelope. It has a vertical travel of 915 mm which allows it to reach objects on the floor as well as objects at table height. Furthermore, it has a 4 kg. lifting capacity which allows it to lift a wide range of objects. High level control of the robot is through an IBM PC/AT compatible computer which communicates with the robot's on-board microprocessors via an RS 232 serial port.

Three Honeywell ultraminiature infrared proximity sensors will be required to allow for an automated grasping algorithm to be developed. Sensors on the robot's grippers can be connected to input/output ports on the robot's microcontrollers through a bank of ten wires in the arm's wiring loom. These wires run from the wrist to the main circuit board where they can be connected to the I/O ports. Two of the sensors will be located at the tips of the gripper's fingers and will point forward to detect objects in front of the gripper. The third sensor will be a "thru-scan" sensor. It will be used to detect objects between the fingers and thus allow for objects to be properly located within the gripper.

The interface through which the user will control the robotic arm is the TI-Speech System voice recognition unit. This system contains two software packages, the *Vocabulary Manager* and the *Transparent Keyboard*™, that allow one to set up a speech recognition vocabulary and overlay application packages with speech recognition, respectively. Each vocabulary can have a maximum of 50 words/phrases and nine vocabularies can be memory resident. One vocabulary can be resident on the speech board while several others can be stored on disk. An average of three seconds are required to to load a vocabulary from the disk to the main memory while only 0.3 seconds are required to load a vocabulary from main memory to the speech board. In addition, each vocabulary can have "trigger words" that cause the system to activate a different vocabulary. This feature allows one to create a hierarchical command structure which reduces the probability of misrecognition of voice commands. With speech recognition active, therefore, a spoken command is recognized and the corresponding keystroke sequence is passed to the application program. In our case, the application package will be the control software that will allow the user to remotely manipulate the robotic arm.

In this project, the user will be required to move the arm to the general vicinity of an object to be grasped and then invoke the automatic grasping routine to grasp the object. There are three modes in which the arm can be moved: manual mode, numeric mode, and interpolation mode. In manual mode, the user initiates motion of the desired joints and the joints keep moving until the user stops them. In numeric mode, the user specifies the desired new position for the arm and then initiates motion of the arm. RTX will then move to this position and stop. Interpolation mode, unlike numeric mode which moves the arm to the new position in the most efficient way, allows the user to specify the path the arm should follow in moving to a new position. In addition to specifying how movement of the arm should be effected, the user is also permitted to specify the control parameters which determine the motion itself. That is, the user can specify the speed and acceleration of the motors, the maximum force that each motor should exert, and the tolerable degree of error associated with the position of the motors. Since in most cases the location of an object is not known *a priori*, the user would need to use manual mode to guide the arm to the vicinity of the object. The commands that would be available to the user, through the voice recognition unit, would permit him/her to move the arm in world coordinates: left, right, up, down, in, out, pitch, yaw, roll, open, and close. Furthermore, the user would also be able to control the speed of, and force applied by, the arm. For instance, three speed and force levels (low, medium, and high) could be provided (Fig. 1).

Once the arm has been brought close to the object the automatic grasping routine would be invoked. This routine would drive the arm in interpolation mode so that the path to be followed for scanning the region could be specified. For example, with the gripper open, the arm, would move sideways from right to left until either a signal is received from the sensors or a specified distance has been traveled. If no signal is obtained, the arm would be moved forward an incremental amount and then would travel from left to right. This process would repeat until a signal is received from either of the sensors on the gripper's fingers. If the arm is moving from left to right and a signal is received from the sensor on the left finger, we could conclude that the left finger is at the left edge of the object. The position of the gripper would be marked and the arm would then move in the opposite direction until a signal is obtained from the sensor on the right finger. This signal would locate the right edge of the object. The position would be marked and then the centre would be calculated. A similar strategy would be used to locate the object if the arm was moving from right to left when the signal was received. Conversely, if a signal is received before the region has been scanned (i.e. the object is, initially, inside the gripper's sensing field), the arm would move to the side of the sensor from which the signal was received until the signal is no longer present. This would locate the corresponding edge of the object. This position would be marked and then the arm would continue to move in this direction until a signal is received from the other sensor. This would locate the other edge. Again, the centre would be calculated. Once the centre position has been determined, the arm would move, in numeric mode, to that position. Then, in manual mode, the arm would move forward until a signal is received from the thru-scan sensor. This signal would indicate that the object is within the gripper's fingers and the gripper would close to grasp the object.

4. STATUS AND FURTHER WORK

At the time of this writing (February 1988), the voice recognition unit has been installed in the PC but the infrared proximity sensors have yet to be attached to the gripper. We are in the process of interfacing the voice recognition unit to the robot. In creating the vocabulary, we are using words that are simple, unambiguous, and meaningful. So far, we have found that short, one word commands are more frequently misrecognized than longer phrases. Moreover, longer phrases better convey the intended function of a command.

Concurrently, we are also investigating the effect that varying the sensitivity of the voice recognition unit has on recognition accuracy. When a phrase is spoken, the voice recognition unit compares the voiceprint to a stored template of voiceprints and rates the match on a scale of one to ten with ten indicating a perfect match. If a match rates greater than the minimum acceptable match, the phrase is recognized. In our testing, we have varied the value of the minimum acceptable match and found that the unit performed best with a value of between four and six inclusive. At values less than four, the unit often misrecognized commands while at values greater than six, the unit did not tolerate the normal variations in speech output. Hence, it often did not recognize commands at all.

In the immediate future, we will attach the three proximity sensors and develop and implement the automatic grasping routine. Once the system is fully functional, we will test it in a clinical setting. We have already recruited eight physically disabled individuals to test the system. In selecting these individuals, we restricted ourselves to a group that have been living on their own in the community for some time. Such experience places them in an ideal position to provide constructive criticism of the robotic aid. Furthermore, their apartments will provide ideal testing areas for the robotic aid once the project moves past the laboratory stage.

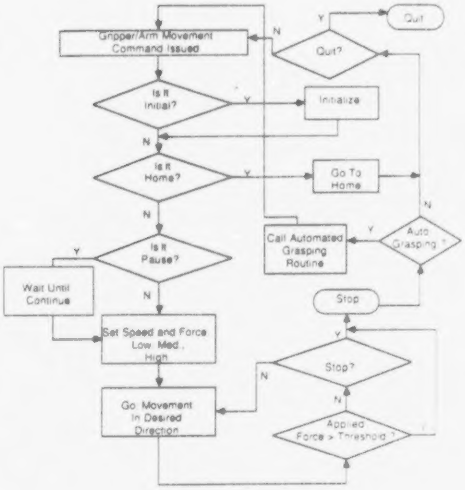
Gripper/Arm Movement Command Issued
Quit?
Y
Quit
N
Is It Initial?
Y
Initialize
N
Is It Home?
Y
Go To Home
N
Is It Pause?
Y
Wait Until Continue
N
Set Speed and Force Low, Med., High
Go: Movement In Desired Direction
Call Automated Grasping Routine
Auto Grasping ?
Stop
Stop?
Applied Force > Threshold ?

Figure 1: Command Flowchart

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USING ENGLISH TO INSTRUCT A ROBOTIC AID: AN EXPERIMENT IN AN OFFICE-LIKE ENVIRONMENT

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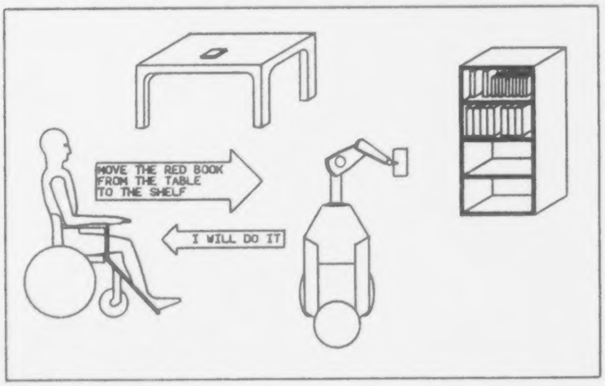
INTRODUCTION

The Robotic Aid now under development at Stanford University [1] will fulfill its potential as an aid for the physically disabled when two things come about: (a) users can speak to the device in ordinary English, and (b) users can teach the device to perform tasks of their choosing. A robot that can understand ordinary English will be accessible to those many people who are not trained in computer programming. And with a robot that can be taught new tasks, the user will be able to adapt the device to his or her individual abilities and needs.

This paper describes recent progress we have made towards these two goals. The work builds on our earlier experience in providing a natural-language interface to the mobile base of the Robotic Aid [2,3,4].

ROBOT DESIGN AND OPERATION

The Robotic Aid consists of a manipulator (a Unimation PUMA 260) and simple gripper mounted on an omnidirectional vehicle. In the current phase of our work we are looking at the robot's use in an office-like environment, a room containing a table and bookshelf on which there are books of various sizes and shapes. We want the user to be able to teach the robot to perform organizational tasks such as sorting the books, packing them into or out of the bookshelf, and rearranging the order of the books on the shelves.


MOVE THE RED BOOK FROM THE TABLE TO THE SHELF
I WILL DO IT

The robot starts with several basic motor Actions: it can open and close its gripper; it can move its gripper from one point to another; it can pick up a single book; it can put a book down on the table or place it upright on a shelf; and it can push a book along the surface of the table.[1]

The robot can also perform certain Tests: it can tell whether the gripper is closed or open; it can check whether or not its gripper is at a specified location; it can tell whether something is in its gripper or not; and it can tell whether or not it is moving its gripper or arm. Tests return the value **true** or the value **false** when executed.

There is no vision system on the robot at present and so we equip the robot with a 3-dimensional map of its environment showing the initial location and orientation of all the objects in the room. Other relevant perceptual properties such as size and color are also made known to the robot. This store of information is called the robot's Database. The robot updates the Database whenever it moves a book from one location to another. Access Functions allow the robot to get information from the Database. There are three basic types of Access Function: one returns information on all objects of a given type (all books, for instances); another returns information on all objects with a given property value (all books that are red in color, for instance, or all books that are thinner than a given size); and the third returns information on all objects that stand in a given spatial relation to some other objects (everything that is **on** the top shelf, for instance, or everything that is **next to** the thin book, or everything that is **between** the big book and the small book).

When an English command is issued to the robot, it is accepted by a program, called the Interpreter, that produces an Interpreted Command. The Interpreted Command specifies three things:

1. The Database Access Functions that allow the robot to determine the location of any object or area referred to in the English command (*the book on your left, the red book,*

---

[1] Some of these motor functions are hard for any robot to do well and will not work perfectly in all circumstances (the "pick-up" action, for instance, will not initially be successful if the book cannot easily be grasped or is at the bottom of a pile, and a heavy book may slip in the robot's grasp and have to be put down and grasped again more firmly). The user will eventually be able to give corrective commands to modify the robot's behavior in such circumstances.

next to the thin red book, to the left of the big book, on the top shelf, for instance).

2. The basic Actions and Tests that the robot must perform to satisfy the user's request. So, for instance, the command *Move the red book from the table to the top shelf* specifies that the red book is to be picked up if it is not already in the robot's gripper, that the arm is to be moved to an empty spot on the top shelf, and that the book is to be put down in that spot.

3. The temporal and logical order in which the Access Functions and robot Actions and Tests must be performed. There are seven different control structures for specifying the order. (SEQ $S_1 \ldots S_n$) designates the sequential execution of S_1 to S_n. (PAR $S_1 \ldots S_n$) designates the parallel or simultaneous execution of S_1 to S_n. (IF x then S_1 ELSE S_2) designates the execution of S_1 if the Test x returns **true**; otherwise if x returns **false**, S_2 is executed. The remaining four control structures are described in [3]. The command *Put the red book on the shelf* will produce the following:

```
(SEQ find-location-of-red-book
     (PAR (IF  red-book-not-in-gripper
                pick-up-red-book)
          find-free-space-on-shelf)
     put-book-down-in-free-space)
```

The Interpreter consists of a parser and a sentence-level grammar. The parser applies the rules of the grammar to the user's command to produce the Interpreted Command. The parser is a CommonLisp version of the D-PATR parser [5] that we have extended to allow interaction with the user and with the robot's Database. If the command is unclear in any way—if, for example, the user says to the robot *Pick up the big book* and there are several that qualify as big books—the user will be asked for more information. The D-PATR formalism allows both the structural properties of sentences to be described (their syntax) and their informational content (their meaning or how they should be interpreted). It is the informational content of the sentence that is represented in the Interpreted Command.

In addition to the Interpreter, there is also a Dialogue Manager, a program that accepts commands from the user, monitors the robot's progress as it obeys the commands, and tells the robot's what it must remember so that it can learn from the user's instruction. For instance, if the user tells the robot how to arrange the books in piles according to their size, the robot must remember what it was told and how it did it so that it can later repeat the same behavior when asked. In this way, the user can build up a set of **learned** Actions that will be added to the robot's basic Actions of "pick-up," "put-down," "push," and so on.

IMPLEMENTATION

The computer onboard the robot is a Digital Equipment Corporation LSI 11/73. The basic robot Actions and Tests are programmed in MicroPower PASCAL (a dialect of PASCAL that explicitly supports multi-tasking) and are executed at a fixed rate of 15 Hz to guarantee smooth motion of the robot. When an Interpreted Command is produced by the Interpreter, it is acquired by a program called the Scheduler. The Scheduler invokes robot Actions and Tests as specified by the Interpreted Command by sending a series of coded commands to the robot over an RS232 cable connection. When one of the Tests returns a value, the Scheduler is activated. It examines the Interpreted Command to determine what to do next—usually to invoke or terminate the execution of some other Action and/or Test. The Interpreter, Scheduler, and Database are all implemented in CommonLisp on a Symbolics 3650.

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DEVELOPMENT OF AN OMNIDIRECTIONAL MOBILE VOCATIONAL ASSISTANT ROBOT

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INTRODUCTION

The development phase of our mobile robot system as a manipulation aid for the severely disabled follows several years of laboratory research in sensors, gripper design, real-time software and the user interface. Our goal is to provide a safe, reliable, and responsive system for use by VA veterans in vocational and daily living activities.

The mobile base is a 3-wheeled vehicle about the size of an electric wheelchair, with an industrial robot arm mounted on it. The vehicle is omnidirectional, so that in addition to moving forwards and backwards and turning, it can shift sideways, making maneuvering in close quarters very natural. The waist-high base has a small PUMA-260 arm on it, plus a 2-fingered gripper for retrieving objects andbringing them to the user, who is seated at a control console. The console is a height-adjustable table with a dock for the robot and a surface accessible to both user and robot. The table holds the user interface equipment.

DESIGN APPROACH

To assure ease-of-use, the mobile system is endowed with sensor systems to help keep the user and itself out of danger. Combined with the omnidirectionality, these systems make our design very well adapted to an environment people inhabit. The development of these sensor systems is of paramount importance in providing the future user population of this technology a high performance and safe robot system.

The first prototype has been stabilized, as far as the construction and programming are concerned. The basic design, real-time software, and user interface have been reported in [3, 4, and 6]. More recently, we have included bumpers for "collision management", a low-power laser scanner for accurate positioning within a room or building, force and proximity sensors on the gripper to locate and grasp objects, and a TV-camera to give the user a good view of the robot's activities. Our goal is to improve this package beyond the prototype stage so that we can be confident of its performance and reliability outside the lab. We are implementing our improvements on a new mobile base, using more reliable components and computer hardware. This process assures that we deliver a robust system to the clinical evaluation counterpart of the technology development team.

RESULTS

The prototype system has been operational for 2 years. In addition to the system-level changes to make the robot more robust, such as power amplifiers and controllers, we have implemented specific enhancements to increase the mobile robot's capabilities. These are discussed below.

- The instrumented bumper system and software to respond to collision situations gives the mobile robot the possibility to detect objects it has not been notified of, and the means to implement strategies for trajectory changes so that it will go around them. Other ideas could be tried, like pushing a chair down the hall.

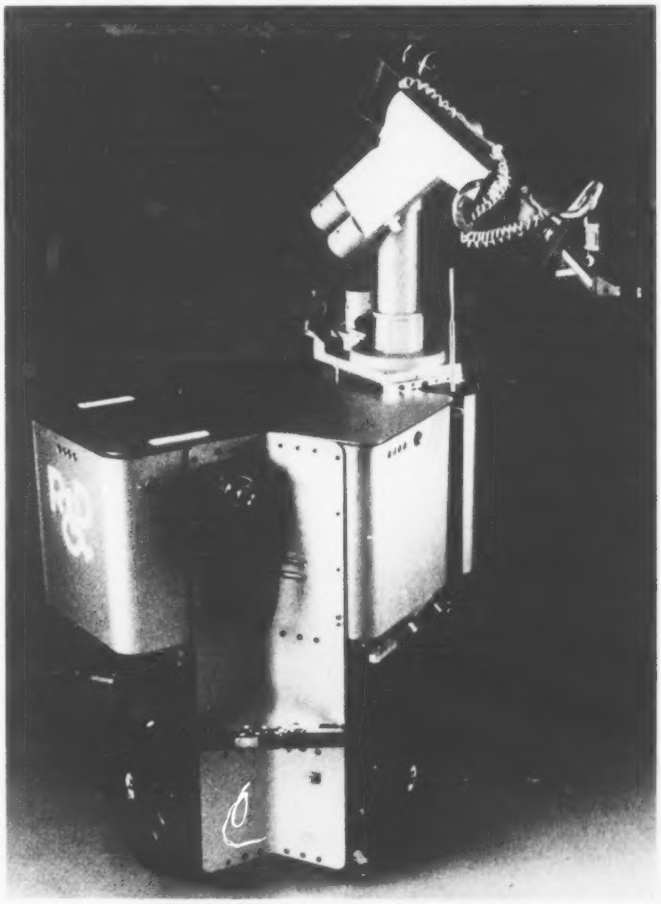

Figure 1. Omnidirectional Mobile Base

- The laser scanner system works in conjunction with fixed wall-mounted reflectors. With every sweep of the beam, the reflections are noted, and triangulation is done to pin-point the true location of the vehicle. Such verification is necessary since errors are inevitable when calculating position by counting wheel revolutions. This type of error increases with time as small deviations accrue over the intended trajectory, and is true for any vehicle with wheels. The scanning needs to be performed about every 10 feet for reasonable (1") accuracy.
- Optical proximity sensors in the gripper are used by different software routines in the real-time computer for a number of phases of handling objects [1]. For example, one algorithm locates a flat surface and aligns the gripper with it (a table, maybe). Another routine uses different proximity sensors to locate a tall object like a can, and finally a routine is invoked which centers the can between the two fingers. All these phases are required for automatic grasping, and all can be done without touching the object or the surface it is on. After this, the object can be grasped for further manipulation [2].
- A 6-axis force sensor for automatic sensing of gripper contact forces with the environment is located between the gripper and the robot wrist joints. The sensor can be used to detect the weight of objects, and can correctly align them when placing them on a surface. The sensor can also be used for pushing buttons on appliances and turning door handles. Finally, the sensor offers an increased level of safety, since every time the robot touches something, intentionally or not, the event is detected, and can therefore be acted on quickly [5].
- A small CCD TV-camera is mounted on the arm for direct viewing of the robot's activities. The operator at the console uses the image to guide the hand and the vehicle. The image can also be used to see who is at the front door, or to preview objects on a shelf before making a selection. Software has been written to use the camera to define trajectories: the user designates a spot on the ground by pointing the camera, and then invoking a command to tell the vehicle to move there. This is a first step in a more ambitious endeavor to develop an object tracking and designating system with 2 cameras installed on pan/tilt mounts.

DISCUSSION

Based on the first system described here, the second mobile robot we are developing uses much less power than the first system due to its high-efficiency power supplies and motor power amplifiers. Also, we have developed a new motor controller system for the 3 wheels and 6 arm joints that consumes one-fifth the power of the current version. These enhancements, combined with a more powerful computer and more powerful motors, give the new system a significant increase in autonomy and performance. Work is proceeding on integrating all of the components and making the base and the console operational as a complete system.

CONCLUSIONS

We have demonstrated the potential usefulness of the system in our lab with several quadriplegic users. While our software in the lab is necessarily geared to system and sensor development, a next phase will require the scripting of task-specific and user-specific software so that the intended users, in our case the quadriplegic veterans at the Spinal Cord Injury Center of the Palo Alto VA, will also have complete access to the system's capabilities.

The future sees our new base completed and in use in a clinical environment with quadriplegics, in typical home and office tasks.

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DESIGN CRITERIA FOR SEATING BASED ON BIOMECHANICS

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INTRODUCTION

From a biomechanical point of view seating provisions for the disabled and those for normals have much in common. The body supporting surfaces must allow for comfort and functionality during a long period of time.

All other requirements related to specific impairments are additional and may not be detrimental for the basic provisions for body support.

Basic biomechanical considerations concerning design criteria can predict which chair is comfortable and which is not for most of the people.

The research in this field has led in The Netherlands to devices of wheelchairs which are known because of their comfortable properties. Research is in progress to determine optimal positions of the person with regard to the handrims of wheelchairs as also the camber of the wheel and other geometrical data. For this purpose a special wheelchair ergometer has been developed with which different propelled masses can be simulated. In the case of automobile seats foolish abreviations from basic rules on biomechanics of seating can be observed. Related dorsal complaints leading to disability are reported.

DESIGN CRITERIA BASED ON BIOMECHANICS

Indismissible body supporting surfaces are arm rest, back rest, seat and foot support. Every surface has its own typical role and numerous examples can be presented to illustrate the mistakes in design made for each. An example is given below.

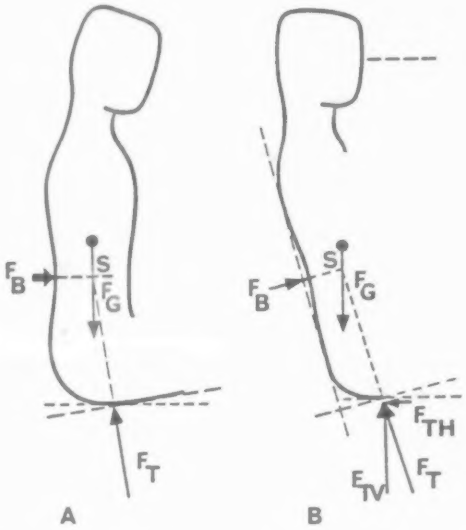

Fig. 1 The back rest and the seat should be approximately at right angles, to avoid shear forces between the lower part of the body and the seat.

Free body diagram of the upper body in passive seating

The weight of the upper body is borne almost entirely by the lower surface of the ischia while one is sitting. On the basis of this fact, it is easy to indicate the relation that should exist between the slope of the seat and that of the back rest. The forces acting on the trunk while sitting are sketched in Fig. 1A. The force of the back rest on the trunk (F_B) and the weight of the upper body (F_G) intersect at the point S. If static equilibrium is to be achieved, the force of the seat on the trunk (F_T) must also pass through the point S. It follows that F_T (acting on the ischia) must slope backwards slightly from the vertical.

Figure 2B shows the trunk leaning further backwards. It follows that F_T must also make a bigger angle with the vertical, if it is still to go through S. Resolution of F_T into a vertical component F_{TV} and a horizontal component F_{TH} shows that on a horizontal surface a frictional force F_{TH} is needed for equilibrium. If one were to try to sit on a slippery (wheel-)chair in this posture, one would slide forward. Sitting on a chair with a rough surface in this position gives rise to shear forces on the skin and underlying tissue which are experienced as uncomfortable or even painful in the long run.

The shear forces vanishes when the seat is tilted backwards so as to be at right angles to F_T. It can be shown that the most favourable situation is obtained when the seat and the back rest make an angle of slightly more than a right angle with one another. If the back rest

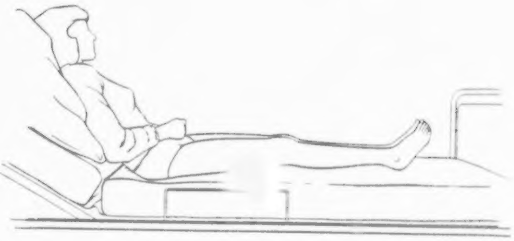

Fig. 2 Sitting up in bed leads to shear forces on the coccyx and the heels, among other places. Cf. Fig. 1, which illustrates how similar forces can be generated when sitting on a (wheel-)chair with horizontal seat. Sitting on the coccyx instead of the ischia can lead to decubitus.

is tilted, the seat should be tilted with it: chairs in which the back rest can be tilted independently of the seat (as found e.g. in aeroplanes) are thus incorrectly designed, from a biomechanical point of view.
Since sitting on a stool does not involve any force from a back rest, the seat can be horizontal in this case.

Sitting up in bed
When a bed is not only used to sleep in, then in view of the restricted field of view when lying down patients sit up in bed for long periods during the daytime. In order to make this possible, hospital beds generally have a hinged portion at the head end which can be raised. The patient can be further supported with the aid of pillows - though one will not sit as upright as one does in a chair. If the rest of the mattress remains horizontal, this situation has a number of undesirable consequences from a bio-mechanical point of view.

- Firstly, the pelvis now rests not on the ischia but on the coccyx, which is much more sensitive to pressure (Fig. 2).
- Secondly, this position, like that illustrated in Fig. 1, gives rise to shear forces on the skin and underlying tissue.
- Thirdly, when one sits up in bed in this position for a long time the trunk will gradually slide down over the pillows, the nightgown or pyjama jacket will ride up and wrinkle and the underpants will come to sit tight in the crotch. Tall people will have the advantage here that their descent will be halted when their feet come against the foot end of the bed.

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THE INFLUENCE OF INCLINED WEDGE SITTING ON INFANTILE POSTURAL KYPHOSIS

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INTRODUCTION

The postural alignment and trunk control during independent sitting sets the precedence for further developmental milestones. In normal infant development, the independent sitting posture is appreciated at approximately six months of age. It is characterized by chin tucking, neck elongation, and an erect spine with the pelvis perpendicular to the support surface. The ability to maintain this posture when placed, is due to the strengthened extensor musculature of the spine and the hips (1). Without this preliminary extensor strength, as in normal development, the developmentally delayed infant is not likely to assume qualitative alignment in the sitting posture. Instead the child may appear to "sink into gravity" at the pelvis causing a posterior pelvic tilt. As a result of this, the spine becomes kyphotic. In order for the infant to compensate for this excessive amount of flexion, the neck often hypersextends (2).

The pelvis is the base of support in sitting and affects the spinal contour. Since a posteriorly tilted pelvis is known to contribute to kyphosis, it was felt that by changing the pelvic angle, the trunk posture would also change. The purpose of this research study was to determine the influence of a posteriorly inclined surface on the kyphotic sitting posture of developmentally delayed children. The researcher felt that the results of this study would be significant in promoting postural changes to improve alignment in sitting.

METHODS

There were sixteen subjects participating in this study. There were eight females and eight males, ranging in age from eight to 36 months. Eight of thises children had the diagnosis of cerebral palsy, four had Down's Syndrome, three were classified as developmentally delayed, and one was a congenital paraplegia secondary to a lumbar level myelomeningocele. All of the subjects demonstrated delays in their gross motor milestones. Their sitting postures were marked by a spinal kyphosis, a posterior pelvic tilt and lowere extremity flexion, external rotation and abduction. The instruments used were a portable video camera, two foam wedges, rubber darts for markers, and a background grid. Each subject was placed sitting on a mat with the grid to their right side. The parent or primary caretaker was instructed to kneel in front of the child and hold the legs straight and together. Rubber darts were taped on and used as markers on the following vertebrae: C7, T7, T12/L1, and S1. Each subject was filmed from their left side for sixty second intervals according to the following sequence: on the mat; on the 15 degree incline; on the mat; on the 25 degree incline; and on the mat. The data was collected by drawing vectors between the C7 and T7 markers, the T7 and T12/L1 markers, and the T12/L1 and S1 markers. This was done with a stop frame component on a VCR. The vectors were drawn during the most erect sitting posture for each sixty second interval. The vectors along with a relative vertical line created an angle for the measurement of each segment. These measurements were compare to the relative baseline data, obtained from the measurements on the mat, to determine any postural changes.

RESULTS

In order to measure the amount of change, the vertebral columns of each subject was divided into three segments. The superior segment: C7-T7; the middle segment: T7-T12/L1;and the inferior segment: T12/L1-S1. The difference in each child's posture was observed and measured in two situations. The first compared the data collected from the child sitting on the mat and on the 15° incline. The superior, middle, and inferior segments all showed significant improvement as compared to the baseline. The second situation compared the data collected from the child sitting on the mat and on the 25° incline. The superior segment revealed no significant improvement as compared to the baseline. The middle and inferior segments showed significant improvements as compared to the baseline values.

DISCUSSION

Several reasons may explain the results found in this study. The majority of children demonstrated some degree of improvement in their sitting posture on both of the wedges however

more dramatic changes took place on the larger incline. Although all the children sat more erect on the 15° wedge, the overall postural alignment was more enhanced on the 25° incline. With respect to these findings, the author proposes several possible reasons for the significant outcome. One is the biomechanical aspect of sitting on a posteriorly inclined surface. If this type of surface is used in the presence of hamstring limitations, the sitting posture can be affected. This can happen with muscular limitations whether it is due to hypertonicity and or an actual decrease in the muscle length. When sitting on a posteriorly inclined surface, tension on the hamstrings is released via a decrease in the degree of hip flexion. This can decrease the posterior pelvic tilt, encourage weight bearing on the ischial tuberosities, and facilitate a more perpendicular alignment of the pelvis in relation to the horizontal support surface. In addition, this affects spinal mobility hence the amount of lumbar lordosis increases.
Furthermore, the results suggested that the erect sitting posture was due in part to the body on body righting reaction. When sitting on the posteriorly inclined surface, the inferior portion, being the pelvis and lower spine, developed more extension. As a result, the upper spine and neck appeared to right itself upon the inferior segment. In addition, the upper portion could have possibly been influenced by input from the vestibular system.
The utricular otolith is affected by the sensation of tilt. When the subject is placed sitting on a posteriorly inclined surface, the vestibular system may be influenced as the sensation of tilt is perceived by the utricular otolith. This provides input to the medial vestibular nuclei which relays impulses via the medial longitudinal bundle to the motor neurons of the neck extensor muscles. In turn, the neck extensors contract and influence the upper trunk extensors in an effort to prevent falling forward on the incline. This may contribute to a more erect sitting posture.
With respect to the outcome of this study, the author feels it is necessary to explore its clinical implications. Developmental biomechanics is an important aspect when posture is being considered. It is particularly critical as the spine doubles in length within the first year of life. In development, bone formation occurs with continuous loading. Another point of acknowledgement is the effect the amount of loading has on the direction of tissue growth. More importantly, muscle force has a greater influence on joint alignment than the pull of gravity. In essence, an imbalance or lack of muscular forces secondary to abnormal weight bearing may lead to skeletal deformation, especially over a long period of time(3).

CONCLUSION

In conclusion, this information is relevant when considering the possible complications predisposed to children who precociously sit and demonstrate a postural kyphosis. The results of this study suggest that a kyphotic sitting posture can be significantly altered with the use of a posteriorly inclined support surface.

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WINDSWEPT DEFORMITY AND ITS RELATION TO PELVIC OBLIQUITY, HIP DISLOCATION AND SCOLIOSIS IN CEREBRAL PALSY QUADRIPLEGICS

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INTRODUCTION

Cerebral palsy quadriplegia is often associated with hip dislocation, pelvic obliquity, and scoliosis. Letts et al (5) described windswept deformity as a triad of pelvic obliquity with the dislocated hip on the high side and the scoliosis convex to the opposite side. It is characterized by flexed, internally rotated, adducted hip on the dislocated side; abduction of the contralateral hip (10). These deformities are more pronounced in severely involved than in mildly involved patients (2). Hip dislocation is uncommon in ambulatory patients but is seen in 50-75% of quadriplegic bed care patients (1,3,6). Scoliosis is seen in only 7% of ambulatory patients as opposed to 40% of total bed care patients (9). Pelvic obliquity is seen in patients with scoliosis; 90% of patients with scoliosis have windblown hips. 75% of the patients had iliopsoas and adductor contractures, and in 50% the hip was dislocated or subluxated(9). Pritchett(8) concluded that the unstable hip does not cause pelvic obliquity and scoliosis but rather is frequently associated with it. It is postulated that muscle imbalance and not pelvic obliquity is the cause of the hip dislocation (6). The spastic adductors and iliopsoas are important etiological factors in hip dislocation. Pelvic obliquity and scoliosis cause a loss of sitting balance, decreased use of the arms, increased energy demand, and pressure sores. Scoliosis additionally leads to shorter stature and progressive pulmonary insufficiency (7). When the patient is brought into a weight-bearing position, the pelvis assumes the oblique position with the crest of the ilium higher on the adducted side, with scoliosis of the lumbar spine towards the abducted side. It would be equally plausible that a contracture induced scoliotic deformity may produce a compensatory pelvic obliquity in the reverse manner (4).

This study is to determine the relationship between hip dislocation and windswept deformity, pelvic obliquity and scoliosis.

METHODS AND RESULTS

In a retrospective study medical records of 158 cerebral palsy quadriplegics seen in the Seating Clinic from 1982 to 1987 were examined for windswept deformity, 30 cases were identified. A follow up questionnaire was sent to assess the effectiveness of seating on learning, feeding, spasticity, comfort and mobility. Of 158 patients presenting with cerebral palsy quadriplegia 30 (19%) had windswept deformity; 15 were males & 15 were females; 27 were white & 3 were black. Age indicated that 84% were 8-20 and 10% 21-30 and 6% were above 30 years. The hip joint was dislocated in 83% of the windswept deformity cases; and only 22% spastic quadriplegic without the deformity. Unilateral posterior hip dislocations accounted for 88% of all dislocations.

A left adducted / right abducted deformity in 21 cases, 15 of these had left posterior hip dislocation , 1 had right anterior hip dislocation, 2 had bilateral hip dislocation and 3 had no dislocations. Right adducted / left abducted deformity were found in 9 cases; 8 had right posterior dislocation, and one had no dislocation. Pelvic obliquity was revealed in 93% of patients with windswept deformity and in only 4% without the deformity. Scoliosis was present in 87% of patients with windswept deformity and in only 28% of patients without the deformity. The convexity of the thoracic scoliosis was towards the adducted side in 23 (77%) cases with a lumber curve convex to the opposite side . Four cases (13%) had a lumbar or thoracolumbar C-curve deviated towards the opposite side of the adducted hip.

Of the 30 patients with windswept deformity, 19 had no surgical procedures performed or the surgical history was unknown. Eight patients had adductor tenotomies, 1 of which also had an anterior obturator neurectomy. Three surgical hip reductions were done. 82% of patients fitted with plywood and foam indicated that it is comfortable , 80% indicated improvement in ease of transportation and 70% in patient's mobility; spasticity was slightly decreased in 46% of patients. Those fitted with a contour-U-seating system indicated no marked change in spasticity, 50% believed it was comfortable.

DISCUSSION

Posterior dislocation of either hip joint strongly favored adduction of the ipsilateral side whereas anterior dislocation favored abduction . No dislocation was found in 4 cases. It is probable that windswept deformity happens secondary to bad posture when the patients lie in the prone position particularly with a strong ATNR's (Asymmetrical Tonic Neck Reflex). The high frequency of unilateral hip dislocation with windswept deformity would support a close correlation between the two. Pelvic obliquity and scoliosis occurred more frequently in patients with windswept deformity. Whether pelvic obliquity is secondary to scoliosis or scoliosis is secondary pelvic obliquity is still uncertain. We agree with Samilson (9) that a dislocated hip is usually found on the high side of the pelvis. We also agreed with Prichett (8) that the unstable hip does not cause pelvic obliquity and scoliosis but is frequently associated with it. We agree with Coopperman (2) that there is a link among hip instability, pelvic obliquity, and scoliosis, which is more pronounced in patients with severe involvement, and unilateral hip dislocation. Patients with Unilateral hip dislocation appear to be at high risk for developing pelvic obliquity, scoliosis and windswept deformity. There is a correlation between the dislocated hip and windswept direction, with the hip posteriorly dislocated being on the adducted side in 88% (n=24)of cases. Seventy-seven percent of windswept deformity cases presented with thoracic scoliosis, with convexity towards the adducted side with a lumber curve convex to the opposite side . Patients with a lumbar or a thoracolumbar C-curve deviated towards the contralateral side of the adducted hip. In our study the thoracic/lumber S-curve scoliosis predominated; while Cooperman et al (2) reported that thoracolumbar curves predominated. The efficacy of various surgical procedures was undetermined since it was not known when during the deformity's progression they were performed. We agree with Lonstein et al (6)that muscle imbalance and not the pelvic obliquity is the cause of the hip dislocation. Phelps and Griffith et al (6) showed that the incidence of dislocation increased with the severity of the spasticity,implicating muscle imbalance as an etiological factor in hip dislocation, pelvic obliquity and scoliosis. We believe that a successful reduction of a unilateral dislocated hip is associated with a decreased incidence of pelvic obliquity and scoliosis in cerebral palsy quadriplegic child. It appears that the link is disrupted in some children by reduction.

Several seating devices were prescribed for patients with windswept deformity to accommodate the deformity and to prevent further deterioration. It is too early to give a complete report about the effectiveness of the Contour-U system for patients with windswept deformity. Other systems used were Otto-Bock, C.P. chair, Safety Rehab Chair, M.P.I., DESEMO, and Total contact shell.

CONCLUSIONS

(1) There is an association between unilateral hip dislocation, windswept deformity, pelvic obliquity and scoliosis.(2) Early diagnosis & correction of muscle imbalance of severely spastic adductors and iliopsoas brake the link between muscle imbalance.(3) Over correction of the tight adductors may lead to anterior dislocation.(4) Every effort should be made to reduce unilateral hip dislocation to disrupt the link and prevent windswept deformity.

(5) The best seating orthoses for windswept deformity is still to be found. (6) Thoracic/lumbar S-curves predominated the scoliotic deformity while other studies indicated thoracolumbar C - curves.

(7) In our study all windswept deformities happened in non-ambulatory dependent severely involved quadriplegic sitters.

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TRUNK MUSCLE RESPONSE TO SEATED, WHOLE-BODY VIBRATION IN FUSION PATIENTS AND IN AGE AND SEX MATCHED CONTROLS

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ABSTRACT

A study has been performed to quantify the response of the spinal musculature in patients one year out of successful lumbar fusion. Controls were age and sex matched. The outcome measures used involved the phasic muscle activity of the lumbar region in response to sitting in a steady state, sinusoidal vibration environment. Patients who had had fusions exhibited significantly greater muscle activity than the controls. This has implications in the long term response to fusion operations and to the way the spine responds normally in seated environments.

INTRODUCTION

Although chronic vibration environments lead to problems in the back, we can take advantage of the usefulness of brief vibration exposure as a tool. Spinal fusion is a clinical solution to certain conditions but it changes the mechanical properties of that segmented, flexible column. Little is known about the effect of making rigid a segment of the spine, in a vibration environment.

BACKGROUND

The objective of this study was to determine whether the erector spinae muscles in people with and without fusions responded differently to seated vibration environments. We attempted to address the following hypotheses. Do both groups exhibit phasic muscle activity in response to sinusoidal stimuli? Are the peak forces (or moments) for postural maintenence similar? Does the subjective sensation of the operation of the back correlate with its mechanical behavior?

MATERIALS AND METHODS

28 people were studied for their responses to seated vibrations at discrete frequencies from 3 to 10 Hz. and accelerations of 0.1 g (rms) using previously developed techniques (Seroussi et al, 1987). Of the group, 14 people (8 men, 6 women) who were at least one year out of successful fusion, were compared to 14 age-sex matched controls. Muscle electrical activity from the erector group was obtained via surface EMG electrodes at the L3 level. Muscle activity was calibrated via known mid sagittal plane, seated extension torques for use to compute the torques due to the peak to peak flexion torques or bending moments occurring about the lumbar spine during seated vibration. Foot support was provided to all subjects. The support was fixed with respect to the room and base of the shaker. Subjects were also asked to rate their discomfort before and after the vibration sequence of the test, using a visual anolog scale.

RESULTS

Results of the comfort assessment: Both the fused and non-fused subjects showed no difference in initial, final, or changes in comfort ratings. Results of the muscle torques: One subject and her control were discarded for being out of range. Both the fused and non fused subjects showed significantly ($p<.005$) greater torques when sitting and vibrating than when sitting still. For all vibration frequencies except 6 and 10 Hz, the fused subjects produced significantly more mid-sagittal plane torque than the unfused subjects (3 Hz, $p<.005$; 4 Hz, $p<.025$; 5 Hz, $p<.05$; 7 Hz, $p<.005$; 8 Hz, $p<.01$; 9 Hz, $p<.025$). Subjects with fusions also produced significantly more mid-sagittal plane torque while sitting still than the controls.

DISCUSSION

While spinal fusion can alleviate spinal instability and low back pain, greater demands are placed on the lumbar musculature and may have long term effects, especially in the vibration environment. This experiment has shown a difference in response between the fused and non-fused subjects. It is not clear whether this was cause and effect. This work is limited because it was not possible to determine the fusion patients' response to vibration prior to the fusion. A question is then raised: Does the fusion affect the muscle response or, more intriguing, do the muscles respond in such a way as to lead to mechanical problems in the lumbar region, ultimately requiring a fusion? In addition, the condition of the spine (fused or not) seemed to have no effect on subjective discomfort rating. Hence designing seating environments solely on the basis of comfort may not protect the spine.

CONCLUSIONS

Non-fused subjects and successfully spinal fused patients have been evaluated for their back muscle and discomfort responses to discrete, sinusoidal vibration. Significantly greater muscle activity was found in the post fusion patients but neither group showed any difference in discomfort in their backs.

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TRUNK MUSCLE RESPONSE TO FOOT SUPPORT AND CORSET WEARING DURING SEATED, WHOLE-BODY VIBRATION

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ABSTRACT

Using established protocols, the response of the lumbar musculature was studied in a series of normals (no history of low back pain) to a seated vibration environment while varying foot support or corset wearing. The corset had no significant effect while the subject was sitting statically or while sitting and vibrating. The foot support did have a significant effect. The back muscles were more active in the seated, static posture without foot support than with it. They were also more active at the seated individual's first natural frequency (5 hertz) without foot support than with it. Foot support is necessary to minimize activity in the back.

INTRODUCTION

Low back pain production is a concern of all who drive for extended periods. Determining the mechanical reasons for its onset is therefore quite important. One way of doing this is to study this physical response of someone to a vibrating seat while changing some of the accompanying supports. The objective of this work was to find out if either foot support or wearing a corset had a role in the back's response to vibration.

BACKGROUND

In order to design back supports or seating that will minimize vibration induced loads on the lumbar spine, it is necessary to evaluate the back's response to prototype supports. Estimates of muscle torque were made in the lumbar spines of six seated males undergoing vertical vibration and exposure to corset wearing and foot support.

MATERIALS AND METHODS

Surface EMG data were obtained from the lumbar musculature and converted to torque estimates using previously validated techniques (Seroussi et al, 1987). Six male subjects were exposed to seated, steady-state vibrations for ten seconds at 0, 3, 5, 7 and 9 Hertz at a constant acceleration (0.1 g rms). They were required to maintain a seated posture with a 5-10 degree forward flexion and yet consciously hold the lumbar region in a lordotic orientation. Subjects were vibrated with or without support of the feet and with or without wearing of a Camp lumbosacral corset. The feet were supported with a platform fixed with respect to the room's reference system. When unsupported, the feet were allowed to hang free. All tests were performed twice and in a random sequence. Matched pair Student's t-tests were performed to determine the effects of foot support or corset wearing at each frequency, with the level of significance at .05.

RESULTS

No significant differences in estimated peak to peak torque were found at any frequency between the test and retest of the subjects with feet supported. There were also no significant effects of wearing a corset during vibration at any frequency. However, when the feet were unsupported, there was significantly more back muscle activity in two conditions. First, the back muscle activity was greater in the static condition, when the seat was not shaking and the feet were hanging, unsupported. Secondly, with a 5 Hertz vibration, the back muscles showed greater response and hence greater torque production.

DISCUSSION

Under these conditions there was no discernible benefit to wearing a corset in a seated vibration environment. Foot support did have an effect on the back. First, when the feet were statically hanging, the lumbar muscles were more active, probably in posture maintenance. During 5 Hz vibration, (close to the natural frequency of the seated human) the bouncing, free masses of the upper and lower legs most likely increased the complexity of the postural control task for the lower back muscles. This shows how important it is to support the feet and the masses of the legs in both office and factory seating and during car or truck driving if the loads applied to the lumbar spine are to be minimized.

CONCLUSIONS

The effects of foot support and corset wearing were tested in both static and vibration seated environments. The corset used had no effect on the back response. Foot support had a significant effect on back musculature both statically and near the seated individual's natural frequency.

ACKNOWLEDGEMENTS

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FINITE ELEMENT PREDICTIONS OF LONG-BONE REMODELING

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INTRODUCTION: The bone remodeling theory of Carter and colleagues (1,2,3) is used to predict cortical thickness and density distributions in a typical long-bone cross section subject to multiple loadings. The remodeling theory assumes that bone mass is adjusted according to the intermittent mechanical stresses to which the bone is exposed. Bone mechanical stimulation due to daily activities can be represented as stress histories consisting of i discrete stress states of n_i cycles of stress per day. A region of bone experiencing neither a net loss or gain of bone apparent density is assumed to be exposed to a constant daily stimulus resulting from the daily stress history. Furthermore, it is assumed that the stimulus has the same value at all sites in the bone. If it is assumed that the bone strength is proportional to the apparent density squared, the local bone apparent density, ρ, is given as (2),

$$\rho = K\left[\sum n_i \bar{\sigma}_i^m\right]^{1/2m} \quad , \qquad (1)$$

where, $\bar{\sigma}_i$ is the "energy effective stress" defined as $\bar{\sigma}_i = \sqrt{2EU_i}$, E is the elastic modulus, U_i is the continuum model strain energy density and m and K are empirical constants. In this study the remodeling theory is implemented using various multiple loading histories applied to a three-dimensional finite element model of a typical long bone.

METHODS: A three-dimensional finite element model of an idealized long-bone with a circular cross sectional shape was generated. Multiple loads, each with a prescribed number of load cycles, were created to simulate various assumed daily loading histories. The loading histories which we studied included: 1) 10000 cycles of pure bending with superimposed axial compression; 2) 8000 cycles of pure bending with superimposed axial compression and 2000 cycles of torsion; and 3) 5000 cycles of pure bending with superimposed axial compression and 5000 cycles of torsion. The load magnitudes were chosen to result in periosteal axial strains of 500 $\mu\epsilon$ compression with 300 $\mu\epsilon$ tension and shear strains of 525 to 935 $\mu\epsilon$.

For the first iteration of each analysis the bone was assumed to have no marrow cavity but rather to consist of fully dense cortical bone throughout. For further iterations, the density was altered according to the calculated stresses, resulting in a non-uniform distribution of bone apparent density. New values for the elastic modulus of each element were assigned using a relationship between E and ρ based on literature values. To prevent prediction of bone more dense than cortical bone, a saturation (maximum attainable) density of 1.92g/cm^3 was used. Saturation was assumed to occur with a total daily cyclic bone strain energy density of 4.46 MJ/m^3 corresponding to 10000 cycles of 250 axial microstrain or 10000 cycles of 400 shear microstrain. Using this saturation condition, the constant K in Eq. (1) was calculated to be 6.8×10^{-11} where the units of stress are MPa and the units of density are g/cm^3. The value of m was selected as 4.0 (3).

RESULTS: The predicted density distributions after 15 iterations are shown in Fig. 1a, 1b, and 1c. In this figure the number of cycles of bending loading corresponds to 10000, 8000, and 5000 and the number of cycles of torsion corresponds to 0, 2000, and 5000, respectively. When no torsional loading is present, the resulting cross section resembles a non-symmetric I-beam with a thicker flange at the top (compression cortex). The addition of a torsional load component leads to a cortical region of greatly varying thickness. An equal number of cycles of bending and torsion results in a fairly uniform cortex having a slightly thicker cortex on the compression aspect.

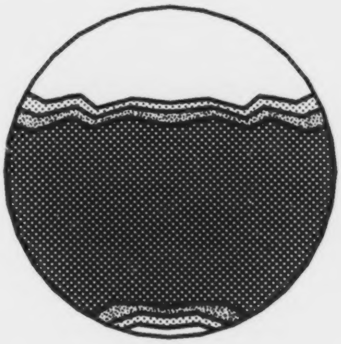

Fig. 1a

10000 Cycles
Bending
+
Compression

0 Cycles
Torsion

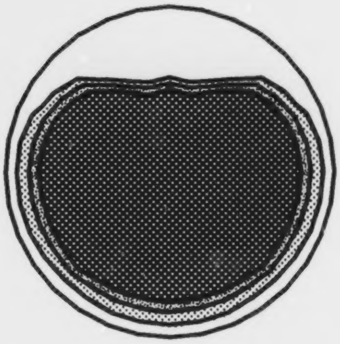

Fig. 1b

8000 Cycles
Bending
+
Compression

2000 Cycles
Torsion

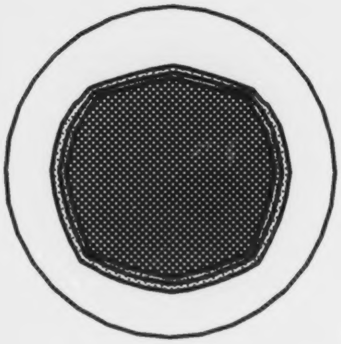

Fig. 1c

5000 Cycles
Bending
+
Compression

5000 Cycles
Torsion

▩ < 0.5 g/cc

▨ 0.5 to 1.0 g/cc

░ 1.0 to 1.5 g/cc

☐ > 1.5 g/cc

CONCLUSIONS: The bone remodeling theory of Carter and colleagues has been used to predict the density distribution in a typical long-bone cross section. Different assumed loading histories resulted in different predicted density distributions. Pure bending with superimposed axial compression but without torsion did not result in a density distribution having a normal physiological appearance. The addition of a torsional load component led to the generation of an endosteal region surrounded by a contiguous dense cortex. The presence of some torsional loading seems to be an efficient way to produce a cortical region of normal appearance. Using other assumed loading histories we have found that the inclusion of additional bending loads in other planes also aids in generating a more normal looking cortical cross-section prediction.

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Structural Analysis of the Rochester Parapodium

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The purpose of this study was (a) to determine the magnitude of forces that must be applied by a child wearing the Rochester Parapodium (1) to result in characteristic hands-free ambulant motions, and (b) to use these forces to determine the magnitude of the stresses present in the orthosis during these motions. Results were obtained using the transient dynamic analysis of the NASTRAN finite element code (2).

The first phase of the analysis process was to determine the magnitude of the forces which the child must impart to the parapodium to result in a forward motion. From observations of children using the parapodium, it was concluded that this forward motion could be described in two distinct parts.

The child first throws his upper body to one side, rotating about the hips in the frontal plane, in an effort to get the ellipsoidal shaped parapodium base onto a single lateral pivot point. At the same time, the child twists his upper body, again about the hips, to create the torque required to cause the parapodium to pivot forward about the point of the base-floor contact. The arms are generally swung during this time to provide additional torque to the parapodium, an action that appears to occur naturally when the body is twisted. As the parapodium pivots forward, the child throws his weight to the opposite side to obtain a pivot point on the other side of the parapodium base. The second pivot point is much easier to obtain than the first since gravity and momentum now aid the child's motion. Therefore the most difficult part for the child is the initial motion; once forward motion has begun it is more easily maintained.

To determine the magnitude of the force and torque required to make the parapodium move as described, a simple finite element model was used. This model consisted of four grids, one for each of the two pivot points on the base, one at the center of gravity (CG) of the child, and one at the center of the base, the latter to allow for the connection of the CG point to the base. These grid points were connected rigidly, i.e., the grids making up the model maintained the same locations relative to each other, allowing no deformation of the structure. One of the base pivot points was allowed to move freely; the other was fixed as a pinned connection that could rotate but not translate. A concentrated mass was placed at the CG grid location to represent a sixty pound child.

A force and torque were applied to the CG point of this model, sufficient to obtain in 0.5 seconds a five degree rotation of the base plate and a four inch forward motion of the free base point.

Four forces or torques were applied as functions of time for the transient solution. The gravitational force (child's weight) was held constant with time. Frictional forces between the base plate and the floor were introduced as rotational torques. A constant frictional coefficient of 0.15 was used to calculate these torques but with reversed sign when the direction of motion is reversed. The lateral force applied to the CG was an up-down ramp that peaked at 38 pounds, the up ramp occurring over 0.05 seconds, the down ramp over 0.02 seconds. The torque placed on the CG was applied 0.1 seconds after the beginning of the lateral force. This torque was ramped up to 15 inch-pounds in 0.005 seconds, held constant for 0.19 seconds, and then reduced to zero. The magnitude and wave shape of these applied forces and torques were selected in part to insure that no unrealistic motions occurred. A few iterations were needed before suitable forces and torques were found.

The second phase of the analysis was to create a finite element model of the parapodium which would be representative of its actual stiffness. The loads determined with the simple model were then applied to the detailed model to determine the stresses present in the structure during operation. In the detailed model the mass of the child was no longer concentrated at a single point but rather distributed in a more realistic manner along the body length.

The child's legs were also included in the model as structural stiffness members, since they are constrained at the knees and the hips. The upper portion of the child's body, represented by a few rigidly connected mass points, was allowed to pivot about the hips as it would when the child used the parapodium. The calculated stresses of this model provided information about the adequacy of the structure of the orthosis.

Four results of the analysis are summarized:

1. The dynamic stress history obtained from the transient solution indicates that maximum stress occurs at the time that motion stops at the point of maximum, frontal plane rotation. As a consequence, a static stress analysis of a properly loaded model is sufficient for design purposes. Run time for the static stress analysis requires about 25% of the run time for the dynamic stress analysis, a considerable saving of resources.

2. Maximum stress occurs at the base of the lateral supports.

3. For the child model used, the stress analysis indicates that the current design of the Rochester Parapodium has a margin of safety of 29 if the orthosis is not abused.

4. Without the added stiffness members for the child's legs, the analysis of the parapodium shows a 12 cps structural vibration. With the added stiffness members, this frequency increases while the amplitude decreases to a negligible level.

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DEVELOPMENT OF A PELVIC MOTION DEVICE

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INTRODUCTION

Poor sitting posture is one of the most likely contributors to the onset and persistence of low back pain (4) and it is generally agreed that good posture includes maintaining lumbar lordosis (1). However, monitoring pelvic motion in standing and seated positions has been difficult. Several investigators have studied the orientation of the pelvis in both standing and seated positions, using either a marking system (3, 4, 5). or television/computer motion analysis system (2, 6). However, presently-available techniques for monitoring pelvic motion are limited. Frequently, motion between the skin and underlying bone result in inconsistent readings of the position of the pelvis. If palpation is necessary to locate bony landmarks, then continuous motion is interrupted.

METHODS

Design

Our laboratory undertook to design a Pelvic Motion Device (PMD) to monitor pelvic motion accurately and continuously in either a standing or seated position. The conceptual basis for the design incorporated previously-used methods of locating the PSIS and ASIS and tracking their movement. Also, to track movement during a dynamic task, a system for continuous monitoring was necessary. Since x-rays would be taken during the testing phase, several additional design criteria were necessary: translucence, so as not to mask the target area; minimal interference with x-ray procedures; ease of adjustability for a range of patient sizes/weights. A plexiglas device was designed and fabricated; all bolts, nuts and washers were made of Delrin.

Testing

A study was performed to compare pelvic motion measurements from x-rays of low back patients with PMD measurements. Thirteen low back patients (8 men, 5 women; mean age = 40; mean weight = 193 lbs. for men, 156 lbs. for women) for whom extension and flexion x-rays were to be taken were recruited to participate in the study. In part, low back patients were chosen because x-rays had already been ordered. Also, we wished to determine whether low back patients could easily tolerate the device.

Radiographs were taken with patients wearing undergarments and gowns. The device was held around the waist while being adjusted to the PSIS and ASIS, then clamped tightly to insure enough pressure on the bony landmarks to hold device in place. Two small lead BB's were attached to the anterior and posterior ends of the PMD as markers. Two lateral x-rays were used to measure the change in pelvic rotation, one of the patient standing in full extension, the second in forward flexion. On the films, a single line, representing the angular position of the PMD to a reference horizontal plane, was drawn between the two BB's. A second line, represeting the position of the pelvis relevant to the horizontal plane, was drawn between the peaks of the anterior and posterior crest of the sacrum. The difference in degrees between the two lines was recorded. Angular tilt of the pelvis was compared to that of the PMD, yielding the error in PMD measurement of pelvic rotation. Each x-ray was marked and measured twice. The measurement with the greatest error was used in the statistical analysis.

RESULTS

The average change of pelvic tilt for all subjects was 26.5°, with a range from 15 to 40°. The average error of recording pelvic tilt with the PMD was 2.07° with a standard deviation of 1.4°. This represents an error of 8.8% in monitoring pelvic tilt with the PMD, with a standard deviation of 7.2%.

DISCUSSION

The largest error in monitoring the position of the pelvis with the PMD was with heavy or obese people. With an excess of fat tissue beneath the skin, the PMD tended to move or shift off the PSIS and/or ASIS more readily. Subjects with minimal fat tissue had less then a 3% error in the measurement. Other factors might account for some of the error. One source is the error involved in marking a point on a curve of the sacral crest. Also, small inaccuracies could have resulted from slight shifting (lateral bending and/or rotation) when patients moved from extension to flexion.

After validating the PMD device, a second device was fabricated to test subjects in sitting postures. This device was constructed of aluminum which is strong and is much thinner and lighter than the plexiglas, since in this case, it would not be necessary to take x-rays. The aluminum PMD can also be contoured to the body much better than the plexiglas, thus making the device less obtrusive. Since the aluminum PMD can be custom-fit to the subject, it is expected that results will be more accurate than those obtained with the plexiglas device.

To record real-time, continuous, three-dimensional motion of the pelvis, the PMD is used in conjunction with a three-dimensional motion analysis system, the Watsmart System manufactured by Northern Digital Inc. This system is a non-contact, three-dimension digitizing system designed for use in biomechanical analysis. Three-dimensional coordinates are obtained by placing infrared light-emitting diodes (IRED) on the PMD. The orientation of the pelvis is then determined by interpolating the trigonometric angles.

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A FLEXIBLE PRINTED CIRCUIT BOARD FOR MONITORING PATTERNS OF FOOT LOADING

Craig A Kirkwood BSc and Brian J Andrews Phd

INTRODUCTION

The reliability of mechanical switches for determining foot contact patterns during gait is limited by lack of threshold control, contact bounce and mechanical fatigue of the moving parts. In addition, a switch gives little indication of the foot/shoe insole force or pressure.

We have previously reported an alternative method using low cost Force Sensing Resistive (FSR) films for an FES orthotic control application (1).

METHOD

The commercially available sensor comprises a conductive polymer film whose resistance is related the applied pressure. The film is positioned on top of two printed circuit grids of parallel interleaving conductors. This forms a circuit of multiple parallel resistances. The polymer film is typically less than 0.254mm thick and is printed onto a thin mylar substrate.

In our earlier development (1), four FSRs were mounted onto a 1mm thick polypropylene insole. Copper foil with a conductive layer of adhesive (3M Ltd) was affixed to the terminal pads of the two grids and connecting wires were then soldered to this foil. This electrical connection system produced intermittent loss of contact after only a few hours use of the insole during normal walking activity.

A solution to this was found in replacing the individual conducting grids and electrical connections with a custom designed flexible printed circuit board (FPCB). Connection with the external wiring was made outside the shoe using a five pin, snap-on FPCB connector. The FPCB consists of a 125 micron thick flexible polyester substrate bonded to a 35 micron layer of copper. Polyester, whilst being relatively inexpensive, offers the advantages of having very low water absorption (<0.3%), excellent dimensional stability and good flexibilty (3).

The Interlink Electronics FSR film (2) was trimmed to the required size and positioned on the grid area. Computer generated masks allow insoles to be made for standard shoe sizes. The FPCB can also be conveniently trimmed to size with scissors. For our application sensors were positioned under the heel, big-toe and the heads of the fifth and first metatarsals.

The FPCB design is shown in Figure 1. Exposed copper tracks were protected with pcb varnish. Once the FSR disks were positioned the insole was covered with a protective layer of polyester.

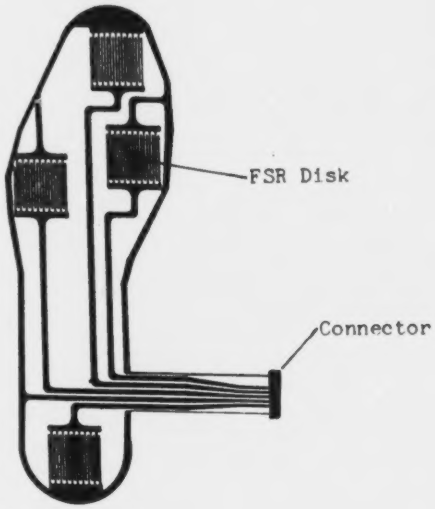

Figure 1

TYPICAL SENSOR CHARACTERISTICS

Using an Instron type 1185 the calibration curve of the FSR was determined. The FSR was cycled between 10N and 900N for a number of cycles of duration 1 minute with applied force and resistance being sampled at 10 Hz.

The resulting curves for the first three cycles are shown in Figure 2. The device exhibits non-linearities, hysteresis and preconditioning effects.

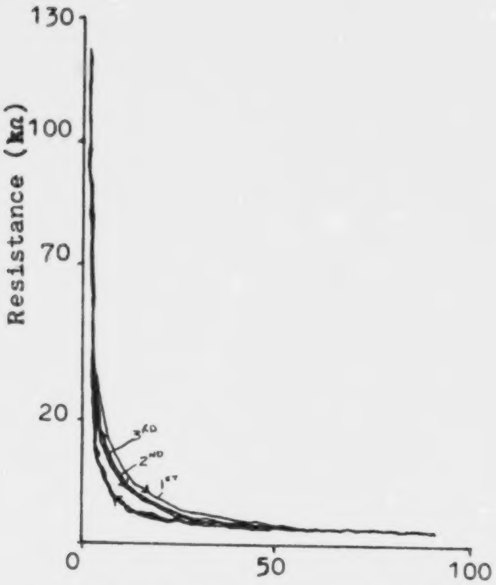

Figure 2

However, only about five cycles are required to fully precondition the device after which the characteristic is stable.

Although non-linearity and hysteresis are evident, it was possible to calibrate for the applied force. This can then be used to determine thresholds such as no contact, contact, partial weight-bearing and full weight-bearing. The threshold levels for switching being set in either hardware or software.

RECORDING FOOT CONTACT PATTERNS

Foot contact events during gait were recorded using a coding scheme to give a graphical representation of the patterns. Contacts of toe, heel, fifth and first metatarsals are encoded as 1, 2, 4 and 8 units respectively (4). Thresholds were set empirically to indicate shoe-ground contact and at each recorded instant the values were summed and plotted. The results from such a test, using analogue comparators, is shown in Figure 3. This was found to be visually easy to interpret and provides information about the temporal pattern of foot contact from which specific gait events can be inferred.

DISCUSSION

The mounting of force sensing resistive films on a flexible printed circuit board offers significant advantages over mechanical switching in terms of reliability and robustness. Analogue signals corresponding to applied pressure are available allowing adjustable switching thresholds to be used.

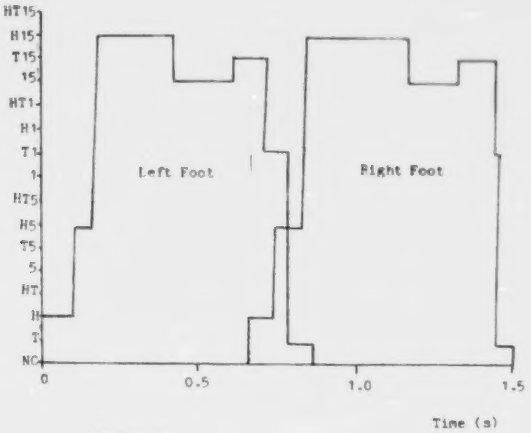

Figure 3

Using calibrated, preconditioned insoles the insole sensor was used to estimate limb loads by summing the output of all four sensors. In addition, by applying appropriate ratioing factors to the values of each of the four FSRs an estimate can be made of the subject's centre of pressure. These variables have been used in control systems for functional electrical stimulation (FES).

ACKNOWLEDGMENTS

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Materials for the FPCBs were kindly provided by GTS Flexible Materials Ltd, Bracknell, UK.

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"SPECIAL INTEREST GROUP". 15

Information Networking
Réseaux de diffusion de l'information

DATA BASE VS. INFORMATION BASE: PRELIMINARY ANALYSIS OF A COMPUTERIZED INFORMATION BASE IN REHABILITATION TECHNOLOGY

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Gregg C. Vanderheiden, Ph.D.
Peter Borden, M.A.
Trace R&D Center, Waisman Center
University of Wisconsin-Madison

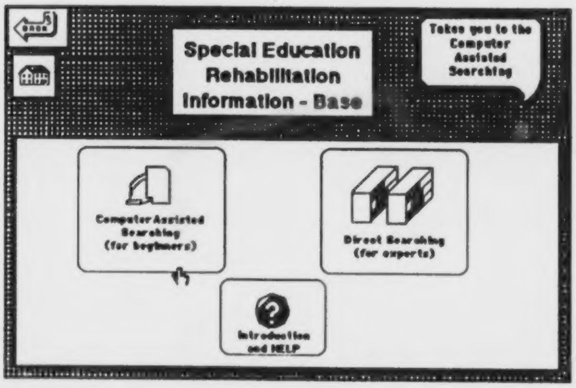
Over the past few years both popular literature and rehabilitation technology leadership has documented the need for making information available to those who need it. In 1982, Naisbitt described the increasing societal dependence on information in his landmark book Megatrends. In 1987, the NIDRR mandated that Rehabilitation Engineering Centers must implement information dissemination/utilization activities as a core component of their programs.

In recognition of the need for good information and widespread dissemination, The Trace Research and Development Center has targeted information dissemination as one of its priorities over the past decade. These experiences have provoked a variety of questions and issues. A current critical question is, "How effective are the various methods of implementing information resource programs?" Recently, the Trace Center has re-examined some of its own activities, performed a needs analysis by compiling information requests received at the Center, and assessed a pilot computerized information base with a semi-expert front end.

DATABASE AND INFORMATION BASE NEEDS

Analyses of information requests at the Trace Center highlighted the fact that there are three distinct categories of information needs in the field. The first is the type of request which desires an answer to a specific question and is looking for a very specific piece of information or data. For example, many individuals ask where they can obtain a given product and how much it costs. The second type of information need is more investigative. Some users (who are usually already experts in the field) want to know more about a topic. Their need is to browse data as in open reference stacks at the library. The third type of request for information is most general. These are more exploratory in nature. Examples of questions emerging from this type of need are "What would be the best communication system to purchase for a friend of mine who has trouble speaking?" or "Our therapy clinic is going to begin providing some technological types of support services. What do we need to get the program underway?", or "I have a blind child, what should I know about technology?"

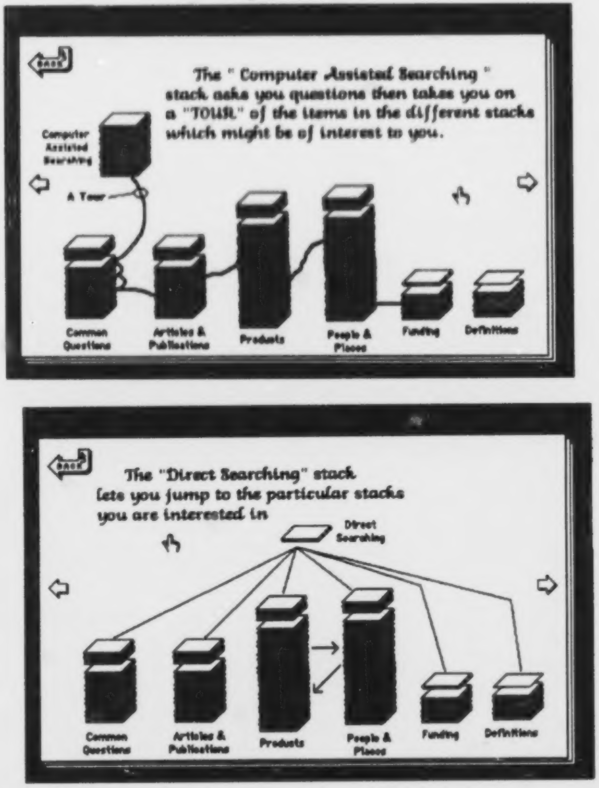
Figure 1


Special Education Rehabilitation Information - Base
Takes you to the Computer Assisted Searching
Computer Assisted Searching (for beginners)
Direct Searching (for experts)
Introduction and HELP

These are substantially different types of needs and consequently require different types of information access. The first requires quick access to a database to recall specific details. The second demands a versatile browsing ability in a wide variety of resources. The third requires a more interactive and probing response to clarify the information needed. The wide variance in questions precipitating from these three needs necessitates a sophisticated system for selecting and dispersing information.

The Trace Center Information Program has implemented several strategies to confront this problem. The Trace Center regularly meet for "Info Rounds", a group information-sharing

Figures 2 & 3


The " Computer Assisted Searching " stack asks you questions then takes you on a "TOUR" of the items in the different stacks which might be of interest to you.

The "Direct Searching" stack lets you jump to the particular stacks you are interested in

Computer Assisted Searching
A Tour
Common Questions
Articles & Publications
Products
People & Places
Funding
Definitions
Direct Searching
Common Questions
Articles & Publications
Products
People & Places
Funding
Definitions

and problem solving forum, to discuss the spectrum of questions and requests received, and to allow team members with expertise in different areas to share perspectives. The Center also devotes substantial information personnel time specifically to updating information resources, houses a resource library for staff, and schedules frequent inservices.

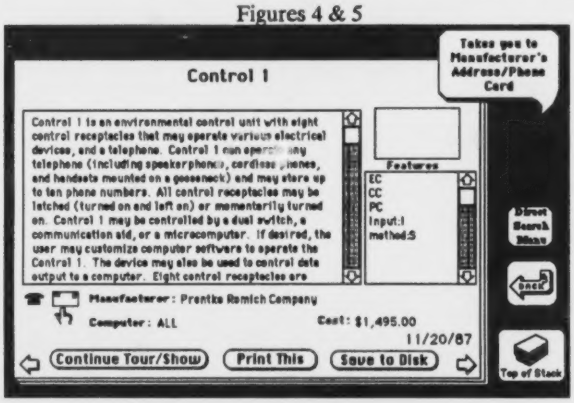
However, the efficient identification and distribution of information for a request remains a substantial challenge. This is in part due to the diversity of requests, the limitations of paper file organization schemes, the finite memory of human beings (even experts), and constraints on available personnel resources for in-depth searches.

Consequently, the Trace Center began investigating the possibility of developing a semi-intelligent front-end to its system of information files and databases. Such a system would have to deal with the three types of information requests coming into the Center.

THE INFORMATION BASE

The design team identified that what was needed was not a front-end to a single database, but a front-end to a variety of databases which contained a variety of types of information. The purpose of the front-end, then, was to integrate the set of databases and provide intuitive methods of entering and access information which satisfied the three types of information needs. The design called for was not one of a **Database** (a set of data in a single organized structure), but an **Information Base**. This Information Base had to provide a direct "quick find" strategy, a browsing strategy and "question clarification and selection" strategy.

Figures 4 & 5



Control 1

Control 1 is an environmental control unit with eight control receptacles that may operate various electrical devices, and a telephone. Control 1 can operate any telephone (including speakerphones, cordless phones, and handsets mounted on a gooseneck) and may store up to ten phone numbers. All control receptacles may be latched (turned on and left on) or momentarily turned on. Control 1 may be controlled by a dual switch, a communication aid, or a microcomputer. If desired, the user may customize computer software to operate the Control 1. The device may also be used to control data output to a computer. Eight control receptacles are

Features

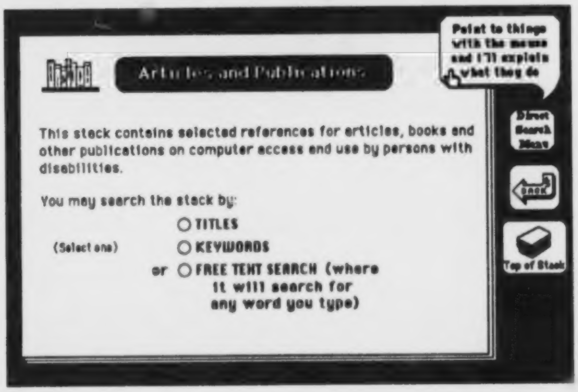
EC
CC
PC
Input:I
method:S

Manufacturer: Prentke Romich Company

Computer: ALL

Cost: $1,495.00

11/20/87



Articles and Publications

This stack contains selected references for articles, books and other publications on computer access and use by persons with disabilities.

You may search the stack by:

(Select one)
○ TITLES
○ KEYWORDS
or ○ FREE TEXT SEARCH (where it will search for any word you type)

Point to things with the mouse and I'll explain what they do
Direct Search Menu
BACK
Top of Stack

A hypertext data organization was selected to pilot design concepts around this information base. Its flexibility in linking information allows information browsing and seemed conducive to designing parallel access strategies. The Apple Macintosh Hypercard was chosen due to its user friendly visual organization, ease of scripting and availability.

This Hypercard system, which we have called the Rehabilitation and Special Education Information Base, commences with a choice of either a direct searching technique or computer-assisted searching technique. Figure 1 illustrates the base card as well as its intuitive mouse driven format. Each of the squares serves as a "button" which will take the user to the different search methods. (The quotation box in the upper right hand corner provides a help cue as the cursor enters any button).

Figure 2 illustrates the card stack system. In this version of the Information Base there are stacks of common questions, articles and publications, products, people and places, funding, and definitions. The direct searching method delivers a user into any stack selected. By contrast, Figure 3 illustrates how the computer-assisted search strategy helps the user clarify the information problem and then takes the user on a tour of all the cards in the different stacks that relate to their question.

Figure 4 shows an example of a specific data card, a Product entry. Figure 4 is linked to another card in the People and Places stack. Clicking on the mouse with the pointer (the hand) in the position shown takes the user to a card showing the address, phone and other information on the manufacturer of the product. Figure 5 shows the top card of the Articles and Publications stack, which links to specific Reference cards.

This study used the pilot version of the Rehabilitation and Education Technology Information Base, and tested the success of the overall conceptual model. The Information Base was evaluated in two ways. First the development team took actual requests and questions received by the Information Section in dry run. The team also tested the Information Base in real time (a) with actual questions coming into the Information Section on the telephone and (b) with on-site information requests.

This study revealed that the basic design premises of the Information Base appear to hold true. A database should permit "quick find," "browse," and "question clarification and selection" access techniques. Secondly, this study revealed that the human interface to the Information Base was one of its crucial features. The difference between data and information is its availability and applicability to those who might use it. This is dependent on the techniques employed to obtain data.

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INFORMATION NETWORKING IN ITALY CONCERNING TECHNICAL AIDS FOR INDEPENDENT LIVING

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ABSTRACT

This paper describes the most recent developments in the Italian information network concerning technical resources for independent living, based upon a computerised Data Bank available on Personal Computers. The technical and organisational aspects of the dissemination of information to users and professionals are illustrated.

INTRODUCTION

The appropriate choice of a technical aid meeting the needs of a disabled individual is a complex process in which a number of aspects need to be taken into account, ranging from the functional limitations to be compensated for, to the social environment and to the motivations of the concerned disabled person.

Information about the available technical aids and their characteristics plays a role of paramount importance in the whole process of delivering technology for independent living, but the best use of available information is achieved when specialised professional assistance is provided in counselling the disabled person, his family and the other professionals involved in his rehabilitation.

In order to meet this need a private Italian rehabilitation organisation (the "Fondazione Pro Juventute Don Carlo Gnocchi") has been working since 1981 at estabilishing a national information network, based upon a computerized Data Bank system and a specialized counselling service (called "SIVA", from the Italian translation of "Technical Aids Evaluation & Information Centre").

INFORMATION HANDLING IN SIVA's DATA BANK

The first version of SIVA's Data Bank was designed in 1982 and its characteristics have been described in literature (see e.g. [1]). It was available only on a mainframe (DEC VAX 11/750) and therefore accessible only through dial-on telephonic line. Since then a continuous improvement has been carried out based upon the actual information needs: the most recent version has been made available on Personal Computers with hard disk, standard MS/DOS operating systems, and a special purpose data retrieval software developped by means of compiled DBIII-plus procedures.

The Data Bank software is highly user-friendly, includes extensive help functions able to guide the data bank user (to whom no experience in informatics is required) to the choice of those pieces of equipment meeting the specific needs of the concerned disabled person.

During the last years SIVA took active part to the development of the HANDYNET project, run by the Commission of the European Communities with the aim of setting up an integrated European information network on the technical and social resources for rehabilitation, independent living and social integration.

In agreement with the criteria developped by the HANDYNET ongoing project, SIVA's own Data Bank has been designed for covering the following aspects of information:

* "WHAT" : technical aids (products) for independent living;
* "WHO": manufacturers, national suppliers and regional dealers, rehabilitation Centres, information centres and associations of disabled;
* "HOW": national or regional procedures for obtaining technical aids.

At present SIVA's Data Bank contains extensive information (about 200.000 data) relevant to some 4000 technical aids and 2000 firms or centres involved in their manufacturing, national an regional distribution, training and service.

The description of each product takes into account the following items:

* The "handyvoc" code (the technical aids classification assumed by the HANDYNET project);
* SIVA's own classification, which encodes the most common names given to every type of

equipment in Italian language;

- The classification of functional limitations, designed by SIVA in order to specify the functional aspects of the device in compensating for a given disability;
- Dimensions and weights.
- The reference to the manufacturer, the supplier and the regional dealer;
- Accessories and optionals.
- Further particular data relevant to selected categories of complex products (e.g. wheelchairs).
- A free-text description, which illustrates the most important characteristics of the product according to the user's point of view.

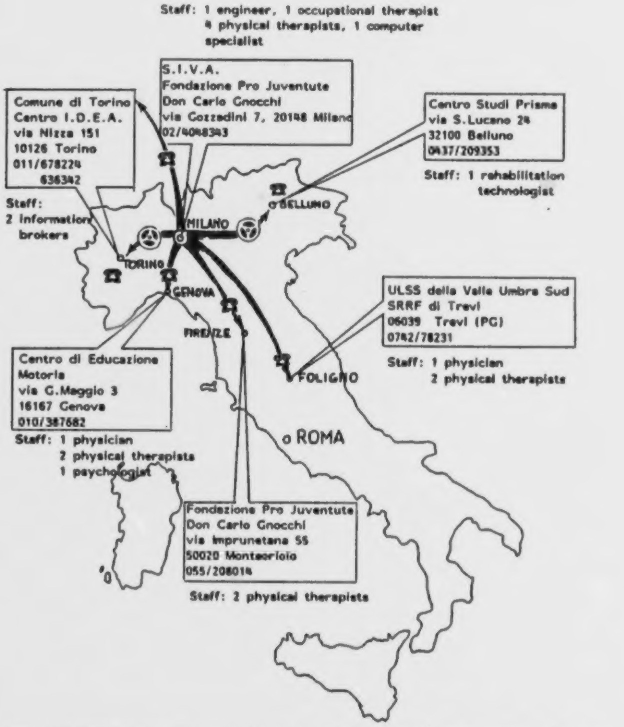
DISTRIBUTION OF INFORMATION THROUGH SIVA' DATA BANK AT NATIONAL LEVEL

Besides to gathering, evaluating, processing, implementing information into the data bank and periodically updating it, SIVA's staff runs its own Counselling Centre (equipped with a permanent exhibition) addressed towards disabled persons, health care professionals, architects and technicians and any other persons concerned with Rehab Tecnology for independent living. Recently SIVA has increased the level of its services through implementing two new projects aimed at:

- directly carrying out the choice and the implementation of technical aids and home adaptations for the most severely disabled persons living at home throughout the Region;
- setting up a technical and functional evaluation programme concerning equipment for independent living.

At the beginning of 1988 five local information Centres located in other Italian regions (fig. 1) were connected to SIVA's Data Bank and other 13 were in process to be connected in the sole Region of Lombardy.

Up to now in the Italian networking experience two models of information delivery at local level have shown to work efficently:


Staff: 1 engineer, 1 occupational therapist
4 physical therapists, 1 computer specialist
S.I.V.A.
Fondazione Pro Juventute
Don Carlo Gnocchi
via Gozzadini 7, 20148 Milano
02/4048343
Comune di Torino
Centro I.D.E.A.
via Nizza 151
10126 Torino
011/678224
636342
Staff:
2 information brokers
Centro Studi Prisma
via S.Lucano 24
32100 Belluno
0437/209353
Staff: 1 rehabilitation technologist
MILANO
BELLUNO
TORINO
GENOVA
FIRENZE
FOLIGNO
ROMA
ULSS della Valle Umbra Sud
SRRF di Trevi
06039 Trevi (PG)
0742/78231
Staff: 1 physician
2 physical therapists
Centro di Educazione Motoria
via G.Maggio 3
16167 Genova
010/387682
Staff: 1 physician
2 physical therapists
1 psychologist
Fondazione Pro Juventute
Don Carlo Gnocchi
via Imprunetana 55
50020 Montoriolo
055/208014
Staff: 2 physical therapists

ITALIAN NETWORKING OF TECHNICAL AIDS COUNSELLING CENTRES (updated 15.1.88)

Model 1. The information centre is located inside a rehabilitation facility and is run by internal designated staff. In this case the disabled user can apply directly to the information office or can be referred to it by the therapist or by the doctor who is taking care of his rehabilitation treatment.

Model 2. The information centre is run by a public or private agency which services various local rehabilitation facilities and social services. Its staff is composed by a Rehabilitation Technologist (a professional specially trained in the choice and implementation of technical aids). In this case the disabled user applies to his local rehabilitation facility or social service, and is referred to the Rehabilitation Technologist by a designated therapist or doctor or social worker.

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REVIEW OF THE NEEDS OF PHYSICALLY HANDICAPPED PERSONS IN THE VOCATIONAL COUNSELING PROCESS AND A POSSIBLE SOLUTION

Sheryl Ranson, Ph.D., Frances Lewis, M.S.
The Magellan Corporation

INTRODUCTION

This paper will describe the results of a study and literature review concerning the specialized needs of physically handicapped persons in the vocational counseling process; a concept that was developed to address these needs; and a computer software program based on that concept that is now available to help address these needs.

BACKGROUND/LITERATURE REVIEW

In 1979, the National Occupational Information Coordinating Committee (NOICC) funded a study through the Florida Occupational Information Coordinating Committee and the Florida Association of Rehabilitation Facilities to examine the special needs of physically handicapped individuals in the vocational counseling process.

This one year study and literature review resulted in the following conclusions: persons with physical disabilities have a need for 1.) occupational information which includes detailed and accurate data on the physical requirements of jobs; 2.) a method to obtain detailed information about the physical capacities of the individual; 3.) a systematic and comprehensive way to compare the physical capacities of the individual with the physical requirements of occupations of interest; 4.) and lastly, a method to consider assistive devices information if there is a discrepancy between what the individual can do and what the occupation requires (4).

This study found that these needs are not met in existing vocational information resources because they use either the disability or the rating method to compare an individual`s physical capacities to the physical requirements of occupations (4).

In the disability method, disabled people are classified into various disability groups such as the spinal-cord injured, the visually impaired, and so on (1). An individual with a particular disability reviews only those occupations feasible for persons with that disability. Using this method can overly restrict and stereotype persons with physical disabilities. This approach also fails to take into account the differences between people. Persons with the same physical disability can differ widely in their capacity to perform the physical demands of occupations.

In the rating method, an individual`s physical capacities are compared to the physical demands of jobs using general or aggregate terms like "light" lifting (1). Many existing systems use this approach. The use of such terms makes it difficult to determine the feasibility of occupations of interest. Using the computer further exacerbates this problem in that entering data like "light" lifting can automatically eliminate a large number of occupations, many of which the individual could potentially do. The computer can very rapidly reduce an individual's choices using this aggregate approach.

DEVELOPMENT OF ISABEL

ISABEL (as in is-able) is a software package that attempts to address the needs identified in the NOICC study. The system is based on the concept that physically disabled individuals should select occupations in the same manner as able bodied individuals; that is, based on their interests, educational level, desired income, etc.; on what they can do, not on what they cannot do. Further, that if physically disabled individuals select occupations in this manner and have access to:

1.) detailed physical demands information on occupations of interest; 2.) a way to compare their physical capacities to the physical demands of these occupations; and 3.) a logical way to search for assistive devices to eliminate problem physical demands, it should increase their occupational choices. (2).

THE ISABEL APPROACH

The **ISABEL** system uses a step-by-step approach to assist the individual with a physical disability to determine the feasibility of occupations of interest. The system uses ninety-five (95)+ physical and environmental factors to describe both the occupation and the career seeker. These factors represent a detailed extension of the physical and environmental factors used in the Dictionary of Occupational Titles (3). The system compares the individual's profile to occupations of interest and reports possible discrepancies between the job requirements and the individual`s physical capacities.

USES OF ISABEL

The original purpose of the **ISABEL** system was to provide needed information to career seekers who have a physical disability. However, **ISABEL** is also useful in the vocational evaluation, vocational training, job placement, and expert testimony aspects of the rehabilitation process (3).

CONCLUSION

ISABEL is a software package that was developed to resolve some of the needs physically handicapped individuals have in the career exploration process. The system includes detailed physical demands data, a method to compare a counselee to the physical demands of an occupation, and a systematic approach to searching for assistive devices. The system is potentially useful in the career exploration, vocational evaluation, and job placement processes and in the provision of vocational training and expert testimony.

For further information contact The Magellan Corporation, P.O. Box 10405, Tallahassee, Florida, 32302 or call 904/681-6520.

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TELEMATICS AND DISABILITY - A CHALLANGE OF TODAY AND THE FUTURE

Jan-Ingvar Lindström

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BACKGROUND

The concept telematics - sometimes also called teleinformatics - has been defined as "the transmission of text, data and pictures." Sometimes it has also been described as a "comprehensive view of telecommunications and information processing from the point of view of needs and profitability for users."

The goal of policy on disability in many countries is integration and normalization. The technical development within the field of telematics moves very fast. It creates problems as well as possibilities for disabled persons.

According to available statistics, at least 10 % of the population in the Nordic countries experience a communication handicap. An increasing number of elderly people have difficulties in coping with modern information technology. /1/

APPLIED TECHNOLOGY OF TODAY...

In the Nordic countries, text telephones are in use in the community of deaf, hard-of-hearing, speech-impaired and deaf-blind users on a daily basis. They are connected to the ordinary telephone network. Also connected are some Information Transfer Centers (ITC), where hearing and sighted interpreters have access to text telephones as well as ordinary ones. Consequently, messages could be transfered via those centers from ordinary telephones to text telephones and vice versa. Communication between text telephones can, of course take place without involving an ITC. /2/

Deaf-blind people can participate via text telephones with Braille displays.

Also, a news service is provided for them so, that daily news are written down on a computer by a sighted operator and stored in the memory, which is connected to the telephone network. A deaf-blind text telephone user is authorized to call the memory, and read the information, i.e. a sort of a daily newspaper for the deaf-blind.

The radio network is naturally per se an interesting tool for information transmission. One application that has been tested extensively in Sweden is to broadcast 60 or 90 minutes recorded excerpts of daily newspapers. A special reciever with a built-in cassette recorder in the home of the visually impaired person allows the "paper" to be recorded automatically, e.g. during the night. -An even more advanced possibility is to make use of the digitally stored information in the compositors computers at the printing houses of modern newspapers. This information - i.e. the full contents of the paper - can be extracted and transmitted in the same way as the recorded ones. (Fig. 1) From September 1987 some thirty blind people in Sweden subscribe to the digital version of the newspaper "Göteborgs-Posten". /3/ /4/

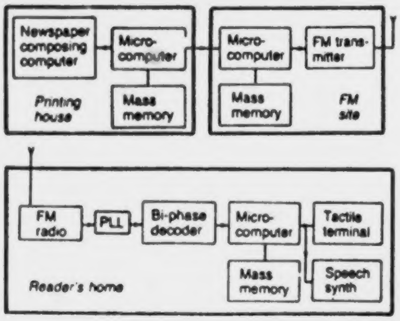

Fig. 1 A schematic outline of the digitalized newspaper (after Rubinstein /3/)

Ordinary TV-programs could be followed even by deaf or hard-of-hearing people with the aid of subtitling - a facility in progress in Sweden today.

...AND TOMORROW

The telephone network - with an increasing amount of service facilities - is of course a very promising - but also challanging - resource for information and communication, not least for disabled persons. /5/
The access to data bases is thereby of great importance. /6/

TV recievers in combination with video recorders have proved to be a very interesting tool for the provision of information to the deaf community. Today, books of various kinds are recorded in sign language and on video tapes and sent by mail to deaf people. -A requested service is the provision of daily newspapers in sign language, distributed via the broadcast network like the present provision of newspapers for the blind.

TV recievers are becoming more and more important, not only for entertainment but also for information in the form of text on the screen. This text could be presented in Braille or synthetic speech with suitable equipment. -A special problem occurs when text is produced as subtitles to movies, interviews etc. which have been translated, because the text must be percieved at a certain (rather quick) speed. There are several possible solutions, however, ranging from syntetic speech to the dialogue being read by sighted persons at the production unit and transmitted via one of two stereo channels, a separate radio channel or perhaps over the telephone network.

If picture transmission to and from individuals could be realized, some interesting applications should be tried. Sign language communications within the deaf community is perhaps the most desired service, but also applications on behalf of the mentally retarded and visually disabled are discussed. A project with remote reading for the latter group has been investigated in a preliminary but promising study. /7/

A PROJECT ON TELEMATICS AND DISABILITY

In Sweden, Telematics is considered so important for integration and participation of disabled people in society, that a special project has been started. The goal is to reveal problems and possibilities and initiate R&D and other activities, in order to overcome problems and take care of the possibilities. The project will run during the period 1987-1989. Several studies have started and reports are available. /8/

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...VERS L'ADAPTATION SOCIALE ET PROFESSIONNELLE:
LE CATALOGUE D'AIDE TECHNIQUE À LA VIE QUOTIDIENNE

BERGERON, Hélène; BÉLANGER, France; CABANNE, Gabriel; POITRAS, Claire

PROBLÉMATIQUE

Tous s'entendent sur l'importance des aides techniques pour le maintien des capacités résiduelles des personnes ayant des limitations fonctionnelles ou pour la compensation d'une incapacité, donc sur leur signification dans l'intégration sociale.

De plus, les courants de pensées des dernières années n'ont fait qu'accentuer la pertinence des aides techniques dans la vie quotidienne étant donné d'une part le nombre croissant de personnes âgées, les progrès de la néonatalité et d'autre part, les volontés gouvernemantales de maintien à domicile, de désinstitutionnalisation et d'intégration sociale.

Pourtant l'accessibilité aux aides techniques rencontre de nombreux obstacles:
- Un manque de diffusion de l'information quant à la variété des aides techniques, leurs caractéristiques, leurs fournisseurs donc une centralisation de l'expertise dans les grands centres.
- Un manque de concertation entre les différents intervenants impliqués dans la prestation des services se traduisant par une information non uniformisée.
- L'absence d'un système d'information précis sur les types d'aides qui sont disponibles pour un problème donné et sur les réseaux de distribution donc difficulté à responsabiliser le client.
- La tendance à rechercher davantage l'aide technique spécialisée plutôt que l'aide technique simple qui répondrait tout aussi bien au besoin du client.
- La diversité des programmes de prestations, leur complexité et leur iniquité.

PHILOSOPHIE ET OBJECTIFS DU CATALOGUE

Le catalogue d'aide technique a été conçu à partir de préoccupations:
- De normalisation.
- De vulgarisation de l'information.
- D'auto-prise en charge de la personne ayant des limitations fonctionnelles ou des incapacités.
- De décentralisation du savoir.
- D'un accès élargi à l'information.
- D'auto-formation.

Plusieurs objectifs sous-tendent notre démarche:

- Reconnaître aux personnes ayant des incapacités le droit de vivre dans leur milieu de vie naturel selon leurs goûts et leurs choix.
- Favoriser la participation maximale de ces personnes aux différentes activités dans notre société.
- Démystifier la problématique de l'adaptation du milieu pour le consommateur, sa famille et l'intervenant non-initié.
- Permettre aux personnes ayant des incapacités de jouer un rôle actif dans le choix d'aide technique.
- Permettre à l'intervenant de première ligne l'accès à l'information dans la perspective d'une meilleure qualité des services.
- Offrir un outil simple et complet qui sans avoir la prétention d'être une liste exaustive du matériel existant fournit les éclairages nécessaires pour guider le choix d'une aide technique.

CLIENTÈLES VISÉES

Ce catalogue traite des indications d'aides techniques, pour les personnes atteintes de déficiences locomotrices, visuelles ou auditives autant enfants qu'adultes.

Aussi, à partir de la philosophie et des objectifs décrits plus haut, ce catalogue est destiné aux intervenants dits de première ligne:
- En réadaptation: centres de réadaptation, centres hospitaliers, centres d'accueil, CLSC, DSC, etc. qui visent l'autonomie de l'individu à tous les niveaux.
- En éducation, partout où l'enseignant peut favoriser l'intégration dans un cheminement pédagogique d'un étudiant qui vit des limitations physiques et/ou sensorielles.

- Dans les organismes de promotion, les associations qui favorisent l'utilisation de toutes les ressources communautaires, tant pour les personnes "dites" handicapées, les personnes âgées ou personnes en perte d'autonomie.
- Il est destiné, bien entendu, aux personnes qui vivent des difficultés de fonctionnement pour diverses raisons déjà citées.

La présentation soulignera particulièrement la facilité d'utilisation de ce document pour les clientèles visées et les aidera à trouver des solutions simples, ou tout au moins à identifier les solutions et les personnes ressources.

Nous soulignerons enfin toute l'importance que représente la complémentarité et la mise en commun concertée des expertises inter établissements "réadaptation physique et sensorielle, réadaptation pour enfant et pour adulte".

La mise au point de langage commun et la vulgarisation de données est possible et a représenté un défi intéressant aux conceptions de ce catalogue qui ont dû dépasser leur profession et leurs champs d'activités traditionnels pour surtout s'entendre sur les besoins des individus et sur le "comment" répondre aux questions du quotidien.

LE PLAN D'INTERVENTION INFORMATISE: un outil au service de la réadaptation

Richard De Courcy, Michel Vallée

L'an 2000... le compte à rebours est commencé

L'informatique est certes l'un des secteurs de l'économie où l'évolution a été le plus rapide depuis 25 ans. Les logiciels développés sont si diversifiés que le commun des mortels est souvent éberlué devant le génie de certaines applications. Paradoxalement, l'utilisation de l'informatique dans la gestion des établissements de santé et services sociaux est demeurée relativement modeste. Préoccupation avant tout comptable, soit la gestion financière et des ressources humaines, bref des applications comparables aux besoins de l'entreprise moyenne.

De plus en plus de personnes s'interrogent sur l'apport de l'informatique dans la prestation des services auprès des clientèles. En effet, tous et chacun reconnaissons le temps et l'énergie faramineux qui sont investis dans la production, la compilation et la consultation des différentes données qui apparaîtront tout au long de l'intervention. Tout en reconnaissant qu'un terminal ne remplacera jamais un clinicien dans les décisions concernant l'avenir d'un client, il est par contre possible d'imaginer son utilité dans l'organisation des données: la compilation ainsi que de la disponibilité en plusieurs lieux d'une même banque d'information. Parmi les éléments constituant le dossier, le plan d'intervention personnalisé représente certes le volet qui bénéficierait le plus d'un traitement informatique.

Le plan d'intervention

Dès 1978, le Centre de réadaptation Lucie-Bruneau optait dans ses politiques de gestion d'organisation des services cliniques pour l'utilisation du plan d'intervention personnalisé (le PIP). Le PIP semblait un moyen pratique de rassembler l'ensemble des objectifs établis pour et avec le bénéficiaire par une équipe multidisciplinaire. Avec les années notre volonté d'utiliser le PIP est demeurée. Cependant nous devons reconnaître que l'application n'a pas été sans poser certains problèmes. Parmi ces problèmes, notons l'absence d'un accès facile tant pour la consultation que pour la mise à jour par plusieurs personnes de différents points de services ainsi que de la compilation nécessaire avant une consultation d'équipe.

Dans le cadre d'un nouveau plan directeur de l'informatique, l'établissement a pris la décision de favoriser une décentralisation de l'information auprès des équipes cliniques en plus de développer un logiciel novateur qui serait un outil aux mains de ces mêmes équipes.

Le développement d'un plan d'intervention informatisé repose sur les objectifs suivants:

- Permettre aux membres de l'équipe multidisciplinaire d'utiliser une banque de données commune.
- Favoriser l'accessibilité à une information validée et en phase brouillon (dossier de travail).
- Permettre des mises à jour rapides et obtenir une synthèse des plans d'intervention avec le minimum de travail clérical.

Moyens préconisés

Pour remplir ces objectifs, le Centre de réadaptation Lucie-Bruneau a développé par l'entremise d'une firme, les systèmes Tyme Limitée, les logiciels nécessaires. Parmi les principes directeurs qui nous ont guidés dans la préparation de ces logiciels, notons l'importance de posséder un langage de 4e génération afin de favoriser des interrogations ad hoc, une compatibilité Macintosh-IBM par l'entremise d'un système central et de favoriser l'utilisation de différentes banques de données dans un système intégré.

Projet pilote

Une expérimentation d'une durée de six mois du logiciel dans une unité de réadaptation de 16 bénéficiaires où travaille une équipe multidisciplinaire d'une dizaine de personnes composée d'éducateurs, psychologue, médecin et ergothérapeute, etc. permettra l'évalua-

Projet pilote (suite)

tion du logiciel avant l'implantation dans tous les programmes de réadaptation de l'établissement.

Contenu de l'exposé

- Présentation du concept du plan d'intervention informatisé,
- Présentation de la solution informatisée privilégiée,
- Présentation en primeur des résultats du projet pilote.

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COMPUTERIZED NETWORKING AND A RESOURCE DATABASE ON TECHNOLOGICAL APPLICATIONS TO FACILITATE THE INTERGRATION OF TECHNOLOGY INTO A SERVICE DELIVERY SYSTEM

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INTRODUCTION

A longstanding problem in the field of rehabilitation technology is the integration of research findings and knowledge about current assistive devices into service delivery systems. In an effort to resolve this problem, the Texas Planning Council for Developmental Disabilities has funded a three-year research-and-demonstration project called The Integrating-Technology-Into-Service-Delivery (ITSD) Project. The goal of this project is to design, implement, and evaluate a model strategy for integrating technology into the present developmental disabilities service delivery system in a large urban setting. The model strategy was designed and is being implemented by a consortium of four education, research, and service delivery organizations in the Dallas/Fort Worth Metroplex: the University of Texas at Arlington (UTA) Graduate School of Social Work, the UTA Center for Advanced Rehabilitation Engineering, the Bioengineering Program of the Association for Retarded Citizens of the United States, and the Dallas Center for Independent Living.

While the model strategy includes many diverse components, the primary focus of this paper is the development and use of a computerized information network and resource database that are available at no cost to professionals and consumers within the geographical area.

NETWORK AND DATABASE FEATURES

The computerized network, called The DD Connection, includes electronic mail and bulletin board capabilities. The electronic mail permits service providers and consumers to exchange personal communications and the bulletin board system permits users to post questions or announcements for all other users to view. The network also provides users near-instantaneous transmissions of files containing longer documents, newsletters, reports, and software of interest. The network is divided into the following correspondence areas:

1. General Message Area
2. Private messages between users
3. Transportation & technology
4. Activities of daily living & technology
5. Health & technology
6. Education & technology
7. Communication & technology
8. Employment & technology
9. Vision & technology
10. Exchange of used equipment & devices
11. Funding of technology
12. Technical questions & answers
13. Latest conferences & workshops
14. Contents of latest publications
15. FidoNet Mail Area
16. ABLED echomail conference
17. Reports from device/technology users
18. Multitasking echomail area
19. Humor is the Spice of Life

The local network uses Opus shareware networking software, which is compatible with FidoNet software, and is one node of an international network of over 1,500 nodes worldwide. This network is unique in that it is totally microcomputer-based, each node being defined by a host microcomputer for the surrounding community and a volunteer system operator. All nodes are synchronized to send and receive mail twice daily. The DD Connection uses Desqview multitasking software with OPUS running in each of two windows to permit two users to be online simultaneously. The host microcomputer for this node is an IBM PC AT with 2 megabytes of RAM, a 60-megabyte hard disk, and two 2400 baud modems.

The computerized database, called The Developmental Disabilities Technology Library, contains a variety of information on technology with children and adults who are disabled. The database is divided into four sections: (a) resource agencies and organizations, (b) experts and users of devices, (c) bibliographic references, and (d) commercial vendors of assistive devices. The database was programmed using R:base 5000 relational database software. Because R:base normally outputs information directly to the video screen, a software patch was programmed to channel the screen-writes to the RS232 serial ports for transmission via the modems to remote users.

METHOD

Two of the primary reasons for including an information network and database in the model were the recognition that knowledge about emerging technologies is, at best, very fragmented and that many service providing agencies typically are "internally focused" and function in relative isolation. The primary purposes for the information network were to pool the available information and expertise in the service community, push the community towards increased technology understanding, and establish interconnections between community agencies. Early in the project the consortium recognized that the critical objectives to accomplish this system change would be to remove the barriers to network use and to provide incentives for increased use to service agency personnel.

When a sufficient number of people participate in a community network, their diverse knowledge is pooled and answers to questions can be obtained almost instantly. The value of the network, therefore, is a direct function of the number of users. Early in the project, we analyzed the reasons for low use in the beginning stages of a network and identified the following barriers: (a) lack of awareness of the network's availability, (b) unfamiliarity and lack of confidence in using the communications, network, and database software, (c) failure to realize how the system could be of assistance, (d) organizational resistance to changing pre-existing communication channels, and (e) cost.

We addressed these issues with five procedures: (a) flooding the service providing agencies in the community with descriptive brochures on the network and database, (b) providing on-site hands-on inservice instruction to service providers, (c) developing interactive tutorial software program that teaches system use when the instructor is not available, (d) insuring that "rich" and timely information was always awaiting callers in each content area, and (e) eliminating telephone charges for any calls within the Dallas/Ft. Worth area. The Opus networking software was configured to track and record data on system use for each user.

RESULTS AND DISCUSSION

Over a four month span, awareness of the network's availability in the community increased substantially. Service providers and consumers who were already computer literate were responsible for a mild increase in network use, while the larger subgroup who had a fear of the unfamiliar software (and hardware) showed few attempts at use. On-site inservice instruction and workshops resulted in another increase in network use by the target audience. An abundance of high-interest and valuable information posted in each of the correspondence areas, along with timely responses to user inquiries, also highlighted the value of network use to many first-time network explorers who were unsure of the applicability of the system to their practical needs.

Eliminating the cost of long-distance telephone calls within the metroplex resulted in another spurt in system use, as people were much more willing to explore the system and thereby discover its benefits when there were no associated costs. The barrier most impervious to removal was the reluctance of administrators and supervisors in service agencies to alter the established communication patterns to allow their staffs to access the network. This finding most likely explains in part the unexpected finding of greater use of the network by consumers, even though it was promoted almost exclusively to service providers. These findings are similar to those observed in a minicomputer-based network operating in Canada (Marlett, 1987).

Repeated users of the network testify to the wide range of benefits afforded by such a communication vehicle, the most frequently cited being the ease of transmitting and acquiring timely information, the savings in time derived from avoiding the "telephone tag" game, and the feeling of connectedness. A regional computerized information utlity, such as that described herein, can be a low cost and effective means of facilitating the integration of technology into a service delivery system, especially as the utility becomes more "user-maintained" as the number of regular users grows.

ACKNOWLEDGEMENTS

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SAN FRANCISCO STATE UNIVERSITY REHABILATION ENGINEERING TECHNOLOGY TRAINING PROJECT

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INTRODUCTION

San Francisco State University, working with the Rehab Engineering Center at Childrens Hospital at Stanford, has begun a new program to train Engineers in Rehabilitation Engineering as well as to train Rehabilitation Counselors in Rehabilitation Technology. Engineers are following a post baccalaureate sequence of courses, fieldwork, and experimental projects; counselors have begun specializing in Rehabilitation Engineering Technology in their Masters level program. All students will gain field experience at the Childrens Hospital and other California Rehabilitation facilities.

THE NEED FOR RET TRAINING

Within the field of Rehabilitation Engineering, much of the development work that is currently going in will be of limited benefit - it is seeking solutions that are unlikely to fit into the real-life situations of most disabled people. This is no surprise to many of the disabled consumers who know what it takes to enter our profession: **No background in disability is necessarily required; no knowlege of previous developments or current state of the art; no actual nor even simulated experience in living with disabilities is required.**

Rehabilitation Counselors are similarly frustrated in their attempts to recommend state-of-the-art equipment to their clients. Most counselors enter the field with a limited background in available equipment, and have little to go on when evaluating the steady stream of new devices.

In addition, a much deeper understanding of the consumer perspective is needed by new rehabilitation counselors and engineers. Without this perspective, much time and money is wasted, and consumers are frustrated in their efforts to live independently.

METHODS

San Francisco State University is in the process of establishing a Rehabilitation Engineering Technology Training Program for Post-Bachelor's level engineers and Masters level Rehabilitation Counselors. The program will be open both to new students and to current professionals.

A University Postbaccalaureate Certificate Program is being developed for engineers; a Masters Program in Engineering Design with a specialization in RET is expected to be in place within a few semesters. A University Certificate in RET is being developed for Rehabilitation Counselors, who can take the course sequence either as part of their Masters program or independently.

The required coursework covers techniques for matching state-of-the-art equipment to disabled people. Problem solving methods are demonstrated as applied to evaluating available equipment, custom equipment, and modified equipment to find the most effective combination for a given disabled person. Engineering students will carry out creative projects, both on campus and in other RET facilities, creating and modifying RET devices. Courses on the medical aspects of disability and on the techniques used in independent living are included in the core curriculum.

RET coursework is taught by Chris Schulenberger, Ralf Hotchkiss, Edna Brean, the staff of the Rehabilitation Engineering Center at Childrens Hospital at Stanford, a network of expert consumer consultants, and staff from area RET's. Training modules for the RET courses are being developed; they will be made available when completed.

Counselors will participate in the choosing and fitting of devices during their fieldwork; engineers will work under close supervision with teams doing modification and customization of RET devices. RET projects are already common here among non-RET engineering students; they will be expanded under this project.

This project is funded under a grant from the NIDRR.
For more information, contact:

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ZERO HANDICAPS IN THE ON-LINE COMMUNITY
COMMUNICATION ON EQUAL TERMS

Judith Blumberger, Shelagh Webster, Yves Poirier, Anne Falcimaigne

ARCTEL is a telecommunications network operating primarily in the greater Montreal region. This computer network while open to the public at large, specifically offers disabled individuals a communications medium and a forum of exchange for the promotion of self-help, independant living, as well as consumer control and choice. ARCTEL acts as an instrument of social change in that it serves to empower its disabled users while at the same time sensitizing all members of the on-line community to the needs and concerns of the disabled. Since computer communications eliminate social barriers imposed by visible handicaps, users of ARCTEL communicate on equal terms without being categorized as either disabled or non-disabled.

Electronic mail, open discussion of issues and file transfers are just some of the system's capabalities. ARCTEL operates on an IBM clone computer equipped with a 20 megabyte hard disk and uses public domaine software entitled Remote Bulletin Board System for the IBM Personal Computer (RBBS-PC).

Background and Objectives

ARCTEL is an acronyme signifying Access and Reintegration to the Community via TELecommunication. Its main objective is the social reintegration of those with special needs by harnassing the advances of computer telecommunications technology and applying them within the context of human services. The approach is both cross-disability and consumer-driven.

Social reintegration presupposes adequate communication and physical contact with the community. It involves the elimination of architectural and attitudinal barriers while simultaneously fostering the principles of de-institutionalization and mainstreaming.

The computer is essentially a communication and information processing device. Once it's hooked up to telephone lines, the computer is transformed into an instrument for socialization. The anonymity of the medium and the flexibility of the technology serve to avoid common social obstacles imposed either by stigma or poor accessibility.

ARCTEL became operational in September 1985, as a result of two years of preparation by Shelagh Webster, a private citizen who was assisting her son with his own bulletin board and the encouragement and help of Judith Blumberger, Director of the Speech Therapy Department at the Institut de réadaptation de Montréal (IRM) who had been using the computer as a communication aid for the speech impaired. The cooperation of four other groups was then sollicited. These groups all shared a common interest and a common point of view; namely, the application of computer technology to an adult disabled clientele. To implement this bold plan, the IRM joined forces with the Centre de réadaptation Lucie Bruneau (CRLB), the Constance Lethbridge Rehabilitation Centre, the Paraplegic Association of Quebec and the Neil Squire Foundation.

Thanks to donations from service clubs (Rotary Club of Montreal and the Easter Seal Society of Quebec) as well as private companies (Macintosh Ltd and Digidial), ARCTEL is adequately equipped. Furthermore, maintenance and programming are done by volunteer programmers who have generously offerred their services.

ARCTEL operates as a free service.

ARCTEL is very user friendly.

ARCTEL via modem: (514) 342 - 5634

System Statistics

ARCTEL has approximately 350 users. Most call from the 514 area code for an average of 11 minutes per call. Fifty one per cent of calls occur by 15h - 22h. Messages are read by 88% of callers while only 32% generate new messages. About 58% use more than one conference. Bulletins account for the most heavily used aspect of ARCTEL at 353% use.

This data has enabled us to ascertain that approximately 33% of our users are active, contributing members while the remainder consult the system very frequently just for information.

As a logical consequence of these statistics, ARCTEL has responded to its users needs. Three publications appear regularly on ARCTEL: 1) La Dernière Heure (OPHQ), 2) Le Réadaptologue (CRLB), 3) Window on Technology (MCSS).

Social Action and Impact

ARCTEL is a network or a medium for information exchange. It differs from a database which organizes and classifies information in a static fashion. The dynamic nature of the information exchange process creates debate, discussion and new needs for information, community action and community response. The following 3 examples illustrate how information exchange generates social action and how it impacts on the community.

Users of ARCTEL quickly discovered that there were no local computer club meetings in an accessible building. The discussion identified a need or a problem and then proceeded quite naturally to the sharing of ideas and suggestions of possible solutions. Within a month, the problem was solved to everyone's mutual satisfaction. The on-line community responded and one club relocated to accessible quarters.

Established communication patterns so often found in organizations and so very resistant to change are being transformed thanks to the communication models provided by l'Office des personnes handicapées du Québec (OPHQ) and Centre de réadaptation Lucie Bruneau (CRLB). In both cases, ARCTEL is used as an official communications medium for their publications.

ARCTEL serves as an extension of the Microlocal at CRLB. Alain Lefebvre and Gil Bruneau work with the residents and the former residents to enable them to use the technology according to their needs. Information exchange and telecommunication are essential by-products of the process once initiated at Microlocal. For example, the publication Le Réadaptologue is summarized and uploaded to ARCTEL as well as other texts pertaining to news or social action.

ARCTEL has also expanded to serve the school aged population. Two school boards have introduced ARCTEL to their students. The teachers simply added telecommunications to the already existing computer curriculum as well as to the life skills curriculum. Thanks to ARCTEL, students in special class are able to communicate with other non-disabled students in different schools. The contact, once initiated via telecommunication stimulates exchange of information and common interests and thus paves the way for good interpersonal interaction when the students finally meet each other at the end of the school year.

This presentation will focus on the importance of communication and the role of telecommunications in the curriculum and in the community. The ARCTEL BBS was the first Canadian BBS for the disabled and has served as the Canadian model of a local network for the disabled. ARCTEL will be used to illustrate the concept of social integration via telecommunication because there are no visible handicaps in an on-line community.

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BEST COPY AVAILABLE

C.R.I.D.E.A.T.

Centre régional d'information, de démonstration et d'évaluation des aides techniques

Louise De Serres,
Ergothérapeute

Le C.R.I.D.E.A.T. est le centre régional d'information, de démonstration et d'évaluation des aides techniques. Mis sur pied il y a 4 ans, à l'Institut de réadaptation de Montréal, le C.R.I.D.E.A.T. a comme rôle d'offrir un service de consultation en vue de fournir les aides techniques les mieux adaptées aux besoins des personnes handicapées physiquement.

Nous offrons les services suivants:

A) Service d'information:
Le C.R.I.D.E.A.T. répond aux interrogations des professionnels et des usagers face à leur besoin en aides techniques par des consultations directes et par l'accès à sa banque de données informatisée contenant des coordonnées exhaustives sur un éventail d'aides techniques commercialement disponibles.

B) Service de démonstration:
Au C.R.I.D.E.A.T., les usagers et les intervenants peuvent, sur rendez-vous, voir et faire l'essai des aides techniques en démonstration.

C) Service d'évaluation:
Au C.R.I.D.E.A.T., l'ergothérapeute consultante peut évaluer les besoins d'un client en aides techniques et lui faire les recommandations appropriées. L'ergothérapeute fait aussi une analyse critique des aides techniques et peut ainsi mieux connaître leurs applications spécifiques.

D) Service de formation:
Le C.R.I.D.E.A.T. offre un service de formation aux étudiants, aux organismes du réseau de la santé et aux différents professionnels concernés par les aides techniques.

Les aides techniques sont indispensables pour un nombre élevé de bénéficiaires, que ce soit dans leurs activités de la vie quotidienne, leurs communications, transports, adaptations domiciliaires, entraînement scolaire ou au travail etc.... Ces services que nous offrons touchent plusieurs des thèmes qui seront élaborés dans cette conférence.

PROMOTING INDEPENDENT LIVING THROUGH PRACTICAL KNOWLEDGE OF REHABILITATION TECHNOLOGY AND LIFE EXPERIENCE OF DISABLED PEOPLE

Christine Huriet, P.T.
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ABSTRACT

The paper discusses the characteristics of the residential courses, run by Centro Studi Prisma. They are addressed at physically disabled adults, with the aim of improving their knowledge of rehabilitation technology and education to cope with problems of disability, to solve them, to help other disabled persons to achieve independent living.

INTRODUCTION

The need of information in the field of independent living and of the technical and practical aspects of disability is deeply felt in Italy. Disabled people in fact have rare opportunities to assess their potential ability to achieve independency before going back home after a long stay in hospital. Many of them have to run across a number of obstacles before finding out their way to integrate themselves into a new familiar, social and professional situation.

Centro Studi Prisma was estabilished in 1984 on a voluntary basis as an interdisciplinary association of people interested in technical and social aspects of integration of the disabled people.

Closely cooperating with SIVA (the Technical Aids Evaluation and Information Centre run by the Fondazione Pro Juventute Don Carlo Gnocchi in Milan) and connected to its computerized information network, concerned with technical resources for independent living, Prisma runs a local Documentation Centre on housing and independent living equipped with a permanent photographic exhibition of technical solutions.

The basic aim of Centro Studi Prisma, is to bring together all the different knowledges and competences involved in the rehabilitation process, and to disseminate the information which helps the promotion of the social integration of disabled people. In this frame the knowledges gained by the disabled themselves through their practical experience of daily coping with disabiity should be considered actually as a professional competence.

In order to give the cultural support necessary to those disabled persons willing to play such a role in society, Centro Studi Prisma decided in 1985 to organize experimentally a summer Course aimed at educating the disabled:

- to improve his knowledge of rehabilitation technology;
- to achieve a better independency;
- to act as counsellor of other disabled persons through making the best use of their personal experience in coping with disability;
- to give his contribution to educating the community to an effective "handicap awareness".

After three courses the experimental stage can be considered finished, and Centro Studi Prisma is now running each summer a residential course.

CHARACTERISTICS OF THE COURSES ON EDUCATION TO INDEPENDENT LIVING

The main point laying behind this initiative, unique in Italy up to now, is the conviction that the personal disabled person's daily life experience in solving practical and social problems is of great value also for other persons experiencing handicap. Therefore a number of disabled persons of different ages, coming from various regions of Italy, are invited each year to spend a week together in order to attend lessons, to exchange their knowledges and their personal experience and in the meanwhile to train each other as professional counsellors on disability.

The participants are 25 disabled adults with medium or severe level of physical disability (usually wheelchair users). Some of the participants attend the course together with their own personal assistant (a relative or a friend).

The course is programmed through one full week, alternating lessons and team works in such a way to provide extensive time for discussion. The lessons cover a variety of subjects, e.g.:

- basic concepts in disability, handicap, independency, rehabilitation and social integration;
- criteria for house adaptations;
- mobility;
- communication, environmental control and computers aids;
- incontinence and prevention of pressure sores;
- family and social aspects;
- access to information resources;
- legal aspects in disability and in provision of technical aids.
- education of the community to handicap awareness.

All these subjects are presented through lessons and demonstrations, supported by audiovisuals and demonstrations of some products (especially as regards mobility aids and communication aids). Some topics, like incontinence and legal aspects are handled by disabled experts. Other topics are presented by experts in the field of technical information.

Each working group is composed of 7-8 persons led by a disabled expert. It carries out a team work dealing with practical aspects of disability, starting from the analysis of daily activities and of the ways in which they can be performed, and illustrating the solutions and adaptations found out by each participant. Of course the participants have very different experiences: some of them have already achieved indenpendent living, other are facing these problems for the first time after discharge from hospital. Town accesssibility, holidays for the disabled and house adaptations are some of the subjects also studied through team work.

Participants are generally very keen on presenting their own inventions or adaptations, with slides, plans of house or flats, demonstrations of personal tricks or original solutions. As regards to the specific field of the equipment for independent living, personal experience of the participants as well as their technical knowledge allows interesting discussions on functional aspects of some products (i.e. wheelchairs and antidecubitus materials). At the end of every working group session each group is asked to give a summary of the discussion to the whole assembly of participants.

At the end of the course each participants is asked to prepare and mail back a homework in the following months. They usually prepare valuable reports about their local everyday's life activities. They obviously give also a useful feedback of the course with comments and suggestions. Many of them said they would like to participate to another course, and increase their competence in this field.

EVALUATION OF THE EXPERIENCE

The results of three summer courses are not to be summarized in a quantitative way: nobody will check the participant's ability and decide whether he "passed" or not. But certainly, people attending this course become able to analyze practical and social problems with an another eye, to seek constructive solutions.

The exchange of knowledge, comes out usefull not only for the more "experts", who by the way become aware of their "peer counselling" role, but also for the disabled with little experience of disability, often unable to face all the problems at once. For them this course is a way to look at practical difficulties through the counselling by people who already solved them, and therefore to look at daily life with a more positive view, to settle at least a psicological independency if not a complete practical independency in life.

The originality of this course, in the authors' opinion, consists in putting a specific knowledge in the hands of the disabled people, giving them the responsability of disseminating information at a "grass root level", through counselling and practical help to other disabled and of course through a positive human relationship. This may be possible only if disabled people recognize their personal experience as a unique and valuable contribution for society.

Besides to organize yearly this kind of course, Centro Studi Prisma has prepared an experimental higher-level course for august '88, designed for disabled people who want to settle down to a counselling activity in the field of technical aspects of disability.

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MULTI-ACCESS REHABILITATION TECHNOLOGY INFORMATION NETWORK: MARTIN

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INTRODUCTION

Trying to provide a national central information resource system poses a multitude of problems and contradictory requirements and constraints. In order for the system to be maintained, it must in some way be centralized. In order to be accessible, however, it must be distributed. In order for the information to be easy to search through, it should be organized and presented in a standard format. The diversity of technologies and support materials, however, requires that the formats for the various types of information be different. Creating a unified system speaks to having a central information generation point. Yet the expertise is distributed across centers and groups across the United States, with no one center being an expert or even "very good" at all areas at the same time. Nor does it seem possible to generate such an all-around expert center. Thus, some network of centers is indicated.

If such a system were set up, the best means for accessing the system is also unclear. Novice users and people unfamiliar with computers would like an interface that is very friendly, and that requires no prior knowledge of the system. More expert users, however, will not want to deal with a cumbersome front end, and will want and need direct, fast command-driven access to the data. Individuals having only one or two questions will want a means for accessing the database that requires no equipment. Individuals who have equipment or have large information needs will want to have the fast access and unlimited printout which can only be achieved from an on-site database. Finally, much of the information must be regionalized, particularly in service delivery areas, in order to be useful.

The proposed approach is a coordinated network of specialized information resources which feeds to a central point where the data is available centrally and through distribution of the entire information base to a virtually unlimited number of sites across the country. Further, this information base is multi-access in that it can be accessed through human beings by telephone, directly over phone lines using any terminal (no special software required), through a command-query system, and through an intelligent computer-assisted searching program (that takes a novice user and, by asking question, determines their information needs and then takes them to all the information in the database that is relevant).

ASSUMPTIONS FOR THE INFORMATION SYSTEM

Basic assumptions for this discussion are as follows:

- The database would be placed in a variety of settings, and used by a variety of users, including consumers, parents, friends, rehabilitation personnel, special education personnel, regular education personnel, librarians, researchers, government agencies, funding agencies, dealers, sales representatives, computer training programs, higher education computer resource centers, etc.
- The users will vary in skill from people who are versed in computer use and database searching to people who are afraid to touch the mouse and computer, and don't understand what they're looking at most of the time that they're looking at a computer screen.
- The system should allow individuals to search for a particular item that they know about as well as to dig around to see if there is anything in the database on a particular topic or problem.
- The database should allow them to search by example (e.g., they could look Vista and then ask for other products which are like it or are related).
- The information should be set up in such a way that could be exported to other database formats.
- The contents need to be aimed at different levels of expertise within each of the different user types.
- The database would contain a wide variety of information, not just product descriptions. Some of the types to be included would be:

1) Product information (description, picture/drawing, manufacturers, cross-linked key words, etc.).
2) Service centers (regional, national, and local)
    - Clinics
    - Repair
    - Special evaluation (list special evaluation areas)
3) Training programs (by area, age group, and topic)
    - Direct training of consumers
    - Training of professionals
4) Funding information
5) Information sources
6) Special interest groups
    - Advocacy (UCP, etc.)
    - Professional special interest groups (SIGs)
7) Comprehensive bibliographic information
8) Selected annotated bibliography of the best documents by topic area
9) Commonly asked questions
10) Novices' introduction to various topic areas (which provide a basic orientation to the topic area, as well as acquainting the reader with basic terminology and concerns/issues which they may want to explore; e.g., when looking for a communication aid, when buying a computer, when trying to locate a clinic for special type of therapy, etc.)
11) State-of-the-art reviews by topic area (documents which gather and integrate the mass of information for a given area into a cohesive and co-

gent whole)

12) Evaluation information by topic area (which provide a review of the best devices, software, etc. in a given area) (This one could be tricky and expensive -- but is necessary in areas where cost is high or quality varies greatly.)
13) Information on search strategies (both electronic search strategies and people/ agency search strategies for information that may not be present in this particular database/ information system)
14) Glossary

- The system should capitalize on individuals and programs that want to do and have demonstrated interest in producing information of the form desired. Generating useful information is a difficult and arduous task. Unless people enjoy doing it, they generally will never get around to it. Also, the database/information system will require different types of information and different types of individuals may be best at generating these different types of information.
- The basic structure of the information system should look like a central reference contact point with distributed resource points. The distributed resource points would be housed at centers which specialize in the various areas of expertise (e.g., communication aids, functional electrical stimulation, lower back pain, etc.). The overall information system would contain individuals carrying out five different functions:
    1) library/archival (collecting, filing and tracking of copies of existing documents and reports). This function would also make copies of reports on request (unless copyrighted and in print).
    2) generation of summary and integrative information
    3) handling of specific inquiries (some electronic and some manual)
    4) evaluation of overall effectiveness of the system
    5) research into better mechanisms, features, strategies, etc., for information generation and response
- The central information referral function (3) would handle questions by sending previously prepared information or referring the person to the expert centers for that area. They would not try to generate individual answers for clients. If frequent questions arise, they would be referred to the information generation function for generation of summative information on that topic area. Provision of specific advice on a topic area (when preprinted materials are not available) would be carried out by the individual expert programs for that area.
- Some generation of summative, integrative information would be carried out at the central information center. Most of it, however, should be generated at the expert research points (e.g., the designated REC, R&T, Independent Living, or other center for that topic area).
- Information generated at expert points should include:
    1) summary description of all commercially available products in their area
    2) bibliography of articles
    3) selected annotated bibliography of publications (formal and informal, published and unpublished) which are most useful in studying the area
    4) lists of resource or clinical programs for that area
    5) annual state-of-the-art paper for research in that area
    6) annual state-of-practice paper for products and clinical practices for that topic area
- The data system should provide multiple points and forms of entry. Among those suggested are:
    1) Human on Phone: a phone line which people can simply call and talk to a human being (should have a rehabilitation background and extensive knowledge of the topic area in question)
    2) On-Line Access: a point where people can access the information over telephone lines (using a computer terminal)
    3) On-Site Access: a means for having the electronic portion of the information system available directly on their own computer

       The on-site version of the database overcomes the problem of slow access to information, which is a severe disincentive to using and perusing most databases. Modern technology allows for the dissemination and storage of large volumes of information in a form that is much less expensive than the communication and connect charges associated with long-distance telephone access. In addition, there would be no monetary disincentive for using the system as there is with phone-in systems. Finally, graphic or picture information can be provided which would be impossible to transmit in a timely fashion over phone lines.

       Smaller items (documents) could be directly contained in such an on-site database. Larger items could be automatically ordered by the system from the central information resource point.
    4) Command Access and Guided Access: For both 2 and 3 above, there should be an abbreviated (command driven) and a guided access path to the data. The abbreviated path would allow people who are familiar with the database to access the information very quickly using commands and keywords. The guided interface would allow individuals who were totally ignorant of the topic and the database to be guided to relevant information through the use of a question-and-answer format which they would carry out with the computer.

       This "guided" inquiry process would require the development of an intelligent front-end for the database. A different type of front-end would be required for the central (over phone line) front end than would be required for the on-site front end, due to the difference in communication bandwidth between the two systems.

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Gerontology
Gérontologie

MICROPROCESSOR-BASED INNOVATIONS AND OLDER INDIVIDUALS: AARP SURVEY RESULTS

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ABSTRACT Introduction of and attitudes toward advanced technology will play a major role in how people of all ages accept and utilize robotic assistants in future service roles. Since the application of advanced and robotic technologies in the service sector, is only beginning, attitudes toward related microprocessor-based innovations (such as computers, automatic teller machines) provide indicators of potential attitudes toward robotic technologies. The Technology Center (TC) at the 1986 Biannual Meeting of the American Association of Retired Persons (AARP) provided an opportunity to begin to collect preliminary information. Questionnaire results in five areas are discussed. The paper concludes with a discussion of the implications of these results for service robots. The paper which provides the supporting detail to this summary is Edwards & Engelhardt, 1987.

INTRODUCTION

Relatively little has been investigated on older people's use of and attitudes toward microprocessor-based technologies. The TC allowed visitors to have hands on experience with a range of state-of-the-art technologies including: personal computers (both desktop and portable), automated gas pumps, automatic teller machines, and credit card telephones. Visitors also had an opportunity to learn about an educational, personal robot. The TC was open two and one-half days during the May, 1986 Biannual meeting and approximately 4000 individuals attended. The layout of the TC was designed to maximize participant flow and comfort in interacting with the technology. The signage was free of "hi-tech jargon" and representatives of both AARP and the vendors were helpfully present at all times (LaBuda & Mullen, 1986). This experience was conducted in a supportive environment conducive to adult learning. Specifically, the four underlying concepts of andragogy: self-directedness, learning readiness, immediate applicability, and problem centered learning tasks (Knowles, 1978) served as guiding principles in the evaluation of the TC.

METHODS

The Health and Human Services Robotics Laboratory designed, conducted, and analyzed evaluative research in order to investigate aging individuals' interactions with computer-based technologies and to acquire basic, baseline, and applied information using the Interactive Evaluation methodology (Engelhardt, 1984). At the last station of the TC, an exit questionnaire was available on two circular tables containing fourteen IBM portable laptop computers. Participants were encouraged to complete the survey before leaving the TC by AARP staff. Approximately 10% of TC participants responded to the 39 survey questions which required 10 -15 minutes to complete. The individuals who chose to answer the questionnaire were a self-selected group of subjects interested in the TC. The instructions appeared at the top of the screen and the question in the middle of the screen. Only one question appeared on the screen at a time to help reduce confusion. The keys needed to answer the survey questions were marked with color coded cues in the shape of stars to facilitate easier use for individuals not familiar/comfortable with qwerty keyboard layouts. The survey consisted of 22 dichotomous questions, 16 Likert Style questions, and one birthyear question. The questionnaire was divided into five areas of investigation: (1)general attitudes toward computers, (2)human factors issues, and (3)demographics and prior experience with selected technologies, (4)effects of their visits to the TC, (5)potential applications for personal computers.

RESULTS

In an effort to focus our initial investigation we restricted our analyses to those individuals who had answered every question and who were at least 50 years of age. Of the 388 respondents who met these criteria, 203 (52.3%) were females and 185 (47.7%) were males; they had an average age of 63.5 years (and a standard deviation of 6.0 years). Approximately two-thirds of the respondents had incomes between $20,000 and $60,000. Average income is approximately $40,000. The mean education attained was a college degree. Over 80% had some education beyond high school (some college, vocational, technical, trade school or taining in the military) or higher. Space does not permit presentation of all the data results; therefore, highlights are only mentioned in the discussion.

DISCUSSION

This subpopulation is of particular interest to Carnegie Mellon's Health and Human Services Robotics Laboratory because this cohort represents more advanced education levels and socioeconomic status which seems to positively correspond to the projected demographics of future aging populations. The introduction of, acceptance of, and use of advanced technology is an important area of exploration for both future and present generations of older persons in order to avoid what Engelhardt terms "technology lag" (Engelhardt, 1984). Opportunities to become familiar with an unfamiliar and perhaps frightening innovations will be necessary in order to integrate the older population successfully into the "computer age". While this research population may not be "the norm" among persons presently over age 50, they do reflect the demographics of the aging population in coming decades, especially as the highly educated and affluent "baby boomers" age.

The **general attitude** questions afford the opportunity to ascertain this subpopulation's perception of technology. While 83.5% stated they were fascinated with and 78.1% stated they were excited about computers, 49.7% also stated they were confused and 61.1% stated they were ignorant. Overall, they believed that computers have made living in our society easier and that one has to understand computers in order "to make it in the world today." They were very positive; however, it was a *self-selected* sample who had chosen to spend some of their conference time visiting the TC in the first place. They were a group who "liked machines." The excellent attendance and participation indicate that many individuals in this population are enthusiastic and they want to learn more about computers. These data indicate that older people are not homogeneously "technophobic" as some stereotypes portray.

The **human factors** questions were designed to survey respondents' more general impressions of the computer-based machines in the TC. Human factors regarding a single technology were not queried because of the multiple and variable experiences users of the TC had the opportunity to explore. Since most (94.3%) had used a typewriter, the keyboard interfaces were familiar and probably comfortable to the TC visitors. In summary, the keys on the keyboards were not too small, not hard to read, not confusing, and were easy to push. However, feedback to the users needs improvement since the respondents had trouble seeing the information on the screens. (For example, backlighting of LCD displays generally improves their readabiliy.) Further research is needed with users who are not familiar with keyboards and alternative inputs, such as voice commands, need investigation at future technology centers.

The questions specifically directed toward assessing the **success of the TC** indicated that people's attitudes had changed positively as a result of their experiences with the TC. Over 80% were more likely to use a personal computer in the future "as a result of the visit to the TC." Over 70% were more likely to use automated gas pumps, over 60% an automated teller machines and credit card telephones as a result of their visit to the TC. The respondents generally felt that the TC was a good use of their time. These results further validate the utilization of andragogical principles for introducing and teaching adults new technologies.

The **potential applications** questions were included to provide an indication of the **applications** for which active, older persons might be willing to employ computers. Word processing, filing, and assistance with taxes were areas where more than 80% of the respondents indicated that they would use a computer. Over 75% also said they would use a computer to assist them in reminding tasks, keeping a medical history and other information on health insurance or Medicare benefits. The responses indicate areas for future software development and suggest ways that personal computers might be combined with universally usable hardware and made more useful to older people.

CONCLUSIONS

This study is unique in its four pronged approach to surveying primary aspects of human-systems integration. It was designed to gather information that can help point us toward future trends and directions for our exploration for solutions to the challenges of an aging society. Both evolving microprocessor technology and our older population are historically unparalleled. Both have important implications for future policy making decisions.

We know little about the activity, functional level, or typing skills of the persons responding. We assume that all were Americans with English as their primary language; however, we did not collect any information on nationality. Most respondents were experienced 'qwerty' keyboard users who had used typewriters and this is a research variable that should be explored further. The roles of labels, cues, and other markings also needs further investigation. These data have been treated as descriptive or 'trend data' because attitudes of "control groups" were not examined and because the respondents were self-selected.

The careful, supportive introduction of older persons (and perhaps persons of all ages) to technologies with which they are unfamiliar is of importance to the acceptance and use of advanced and state-of-the-art innovations. Previous research has also demonstrated this concept of using andragogical principles for introducing robotic innovations to naive users (Engelhardt & Edwards, 1985). Overall, these results indicate that older people are generally likely to adopt technological innovations, e.g. robotic assistants, if the utility of those innovations are apparent to them.

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Seating for the Elderly: A Needs Assessment

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ABSTRACT

The purpose of this study was to better define the existing seating problems and needs of nonambulatory elderly nursing home residents. Two hundered Memphis area residents were interviewed, 184 of whom were wheelchair users and 16 were bedfast. Seventy four percent of the wheelchair users were found to have a seating problem; for nearly 40% the problem was moderate or severe.

INTRODUCTION

Visits to area nursing homes and research reports indicated that many elderly people, particularly those in nursing homes, could benefit from better wheelchairs. An indepth needs assessment was required to more thoroughly define and quantify the problems.

STUDY DESCRIPTION

We administered a questionnaire to 200 randomly selected residents from six area nursing homes. To be included in the study a resident had to be at least 65 years of age and be primarily in bed or in a wheelchair. The questionnaire was composed of sections covering age, medical condition, functional abilities, posture and orthopaedic deformities. Also addressed was the suitability of the present wheelchair, its attributes and problems, and estimated benefits of an improved wheelchair. Whenever possible the residents were encouraged to answer our questions. In cases in which the residents could not respond, we relied on their caregivers for answers.

RESULTS

The average age of all the residents surveyed was 83.6. Ninety-two percent (184/200) were wheelchair users and eight percent (16/200) of the residents were bedfast. By far, the most common diagnosis was stroke (26%), followed by arteriosclerotic heart disease (8.5%), and hip fracture (8%). Thirty percent exhibited orthopaedic deformities such as trunk curvatures and lower extremity contractures which affected their sitting posture. Fifteen percent were reported to have redness or pressure sores over their ischial tuberosities or sacrum.

Results For Wheelchair Users

The average age of those who spent at least part of their day in a wheelchair was 83.5 years. Functionally, 27% of the wheelchair users could walk without assistance. Twenty-one percent could transfer independently. Fifty-one percent propelled their wheelchairs (chairs). Most (41%) spent between 4-8 hours per day in their chairs, 34% less than 4 hours, and 24% more than 8 hours. Fifty-seven percent were restrained in their chairs. When asked if they thought they could sit longer if their chairs were more comfortable or otherwise improved, 30% said yes. Seventeen percent required caregiver repositioning in the chair approximately every hour. Seventy one percent used standard wheelchairs, while 28% sat in "geri" or "stroke" chairs.

Classification of residents' overall seating problems One of the last questions on the questionnaire required a summary rating of a resident's overall seating problem as none, minimal, moderate, or severe. We answered this question in light of the preceding comments, complaints, and observations and with input of the resident/caregiver (Fig. 1).

- * 26% (49/184) had no overall problem.
- * 36% (66/184) had a minimal overall problem.
- * 29% (53/184) had a moderate overall problem.
- * 9% (16/184) had a severe overall problem.

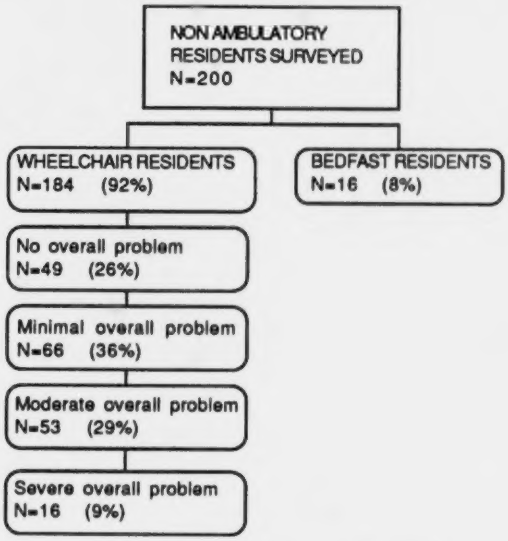
NON AMBULATORY RESIDENTS SURVEYED N=200
WHEELCHAIR RESIDENTS N=184 (92%)
BEDFAST RESIDENTS N=16 (8%)
No overall problem N=49 (26%)
Minimal overall problem N=66 (36%)
Moderate overall problem N=53 (29%)
Severe overall problem N=16 (9%)

Fig. 1: Subgroups of Residents Surveyed

a.) Wheelchair users with a minimal overall problem. When asked what the worst thing about their chair was, 18% mentioned discomfort as the major complaint, 14% reported difficulty moving the chair (or lack of independent propulsion at all in the case of the geri or stroke chairs), and 12% mentioned problems related to sitting posture such as sliding down or leaning to the side (Fig. 2).

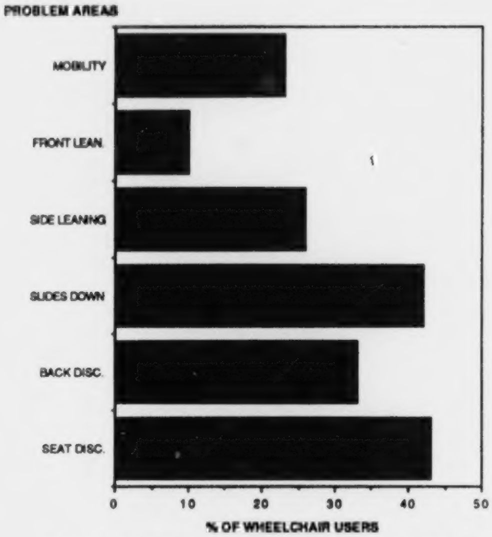

Fig. 2: Distribution of Wheelchair Users' Problems

In response to specific questions, fourteen percent reported pressure sore problems, with the majority of these being minor redness. Minimal and moderate seat discomfort was reported by 47%; minimal and moderate back discomfort was reported by 29%. Sliding down was the most prevelant posture and positioning problem with most (39%) reporting only minimal problems.

b.) Wheelchair users with a moderate overall problem. When asked about the worst things concerning their chairs, these residents were more vocal than the minimal overall problem population. However, the distribution of responses citing discomfort, hindered mobility, and poor posture was nearly identical.

Fifteen percent of this population had pressure sore problems. These residents were much less comfortable than those with a minimal problem, with 70% reporting seat discomfort and 60% reporting back discomfort. The percent and severity of postural problems was higher for these residents as compared to those with a minimal problem, with 34% versus 3% reporting moderate or severe leaning to the side, and 29% versus 9% moderate or severe sliding down in the chair. More of these residents (23%) fell when using their chair than those in the other wheelchair user population subsets.

c.) Wheelchair users with a severe overall problem. This population spent a little less time per day in their chairs than those with a moderate overall problem, with only 1 resident sitting for more than 8 hours. It was indicated that an overwhelming 81% would be able to sit longer if their chairs were improved.

The worst things about the wheelchairs for this population were poor posture (31%) and discomfort (19%). This was the only group for which poor posture was mentioned more frequently than was discomfort. Sixty-three percent had pressure sore problems, 4 times that of any other resident subset.

Results for Bedfast Residents

Eight percent (16) of the residents surveyed seldom left their beds. As a group, the bedfast residents were least able to respond to the questionnaire. Only one resident was able to answer a few of the questions.

Their average age was 84.1 yeas, only 0.6 years older than that of the wheelchair users. Stroke (6/16 = 38%) and organic brain syndrome (4/16 = 25%) were the two most common primary diagnoses. Fifty-six percent had deformities relevant to seating, nearly twice that of wheelchair users (30%). Only 2 were reported to have pressure sores. The caregivers thought that half would benefit from getting out of bed and sitting up. They had tried to seat 6 of the residents, 5 in stroke chairs and one in a standard wheelchair, with little or no success due to moderate or severe side leaning in 5 cases and/or severe sliding out in 2 cases. There were no current plans to seat 31% of the residents due to discomfort, nausea and vomiting, and severe positioning problems involving rigidity, fetal posturing, contractures, and thrashing movements.

EXTRAPOLATION OF SURVEY RESULTS

Extrapolation of the survey results to the Memphis metropolitan area, population 806,000, estimates that there are 1150 elderly nursing home wheelchair users (0.14% of the population) who have a seating problem. Roughly half of these people (590) have a moderate or severe overall problem. Further extrapolation to the US population of 227,000,000 estimates that there are 443,000 (0.2% of the population) who have a seating problem. Roughly half of these, 228,000, have a moderate or severe overall problem.

ACKNOWLEDGEMENT

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LA CONCEPTION DE DOUCHES ET BAIGNOIRES POUR PERSONNES AGEES ET HANDICAPEES

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Introduction

La baignoire traditionnelle que l'on trouve dans un appartement ou une maison n'a guère changé de forme depuis des décennies; elle est difficile d'accès, car l'usager doit enjamber jusqu'à 50 ou 60 cm pour s'y asseoir. De plus, sa surface est dure, glissante et on n'y trouve guère d'endroits pour s'y retenir. La baignoire est, de ce fait, la cause de nombreuses chutes. Si elle est donc dangereuse pour les personnes bien portantes, elle l'est encore plus pour les handicapés ou les personnes âgées. Il est certes difficile de généraliser en disant que tous ne peuvent utiliser une baignoire. Certains le peuvent, mais pour beaucoup de paraplégiques, les tétraplégiques et de nombreuses autres personnes à mobilité réduite il est impossible de le faire.

De cette constatation, Pascal Malassigné, designer industriel et James Bostrom, architecte, ont décidé de repenser la baignoire traditionnelle et de concevoir de nouveaux modèles accessibles à tous. L'étude qui vient de se terminer a commencé à l'Institut Polytechnique de Virginie avec l'assistance financière du National Institute of Handicapped Research et, depuis 1983, avec l'assistance financière du Service de recherche et développement en réadaptation du Veterans Administration.

Pendant ces années de recherche, l'équipe a effectué plusieurs études ergonomiques, des essais de douches et baignoires existantes et surtout la création de nombreux prototypes et leurs essais avec des handicapés. Ces nouveaux modèles de douches et de sièges de baignoires sont le résultat d'une démarche inhabituelle alliant création industrielle et réadaptation fonctionnelle, font l'objet de cette communication à ICAART 88.

1. Création de nouveaux modèles

1.1 Cabine à douche pour usagers en fauteuil roulant

Cette cabine à douche en fibre de verre est formée de deux coques modulaires et de deux panneaux extérieurs. Les coques et panneaux peuvent passer par une porte de 82 cm. La cabine de douche peut être encastrée dans le sol donnant accès direct depuis le fauteuil roulant ou être posée directement au sol. Dans ce dernier cas, l'accès se fait avec une petite rampe.

Robinetterie: La cabine de douche est équipée d'un mitigeur d'eau thermostatique avec un pousse-bouton que l'on active avec une légère pression de la main, du poignet ou de l'avant bras.

Rideau de douche: Le rideau de douche, monté au plafond peut être actionné manuellement avec un cordonnet placé à l'extérieur et à l'intérieur de la douche, ou électriquement avec des pousse-boutons placés aussi à l'intérieur ou l'extérieur de la douche.

Fig. 1: Cabine de douche pour usager en fauteuil roulant, posée au sol avec petite rampe et utilisation des pousse-boutons pour actionner le rideau.

1.2 Cabine à douche pour usagers ayant besoin d'aide

Cette cabine à douche en fibre de verre est formée d'une coque modulaire et de deux panneaux extérieurs. La coque et les panneaux peuvent passer par une porte de 82 cm. La cabine de douche peut être encastrée dans le sol, lui donnant accès direct depuis le fauteuil roulant, ou être posée au sol (accès avec une petite rampe).

Robinetterie: La cabine de douche est équipée d'un mitigeur d'eau thermostatique avec un pousse-bouton que l'on active avec une légère pression de la main, du poignet ou de l'avant bras.

Rideau de douche: Le rideau de douche monté au plafond, est actionné manuellement avec un cordonnet placé à l'extérieur et à l'intérieur de la douche. De plus, un autre rideau couvre la périphérie de la cabine et permet à une auxilliaire de la vie d'aider à la toilette de l'usager sans se mouiller.

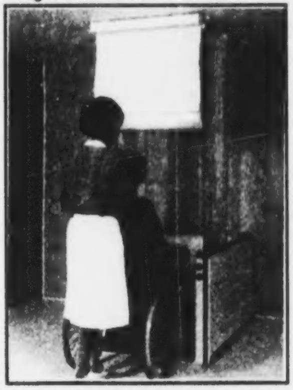

Fig. 2: Cabine de douche pour usager ayant besoin d'assistance

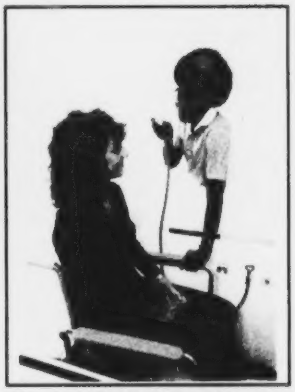

Fig. 3: Auxilliaire de la vie aidant à la toilette sans se mouiller

1.3 Siège couvre-baignoire capitonné

Ce siège, conçu pour des usagers à mobilité réduite pouvant se glisser du fauteuil roulant, s'encastre directement sur une baignoire de 150 cm. Une fois en place, le siège se trouve à la même hauteur que le fauteuil, c'est à dire à 48 cm. La forme de l'assise légèrement inclinée et le dossier du siège stabilisent l'usager et l'empêchent de glisser.
Le siège, réalisé en fibre de verre recouvert de 2 cm de mousse et d'un revêtement en vinyl, est souple pour éviter les risques de contusions ou d'escarres à l'usager.

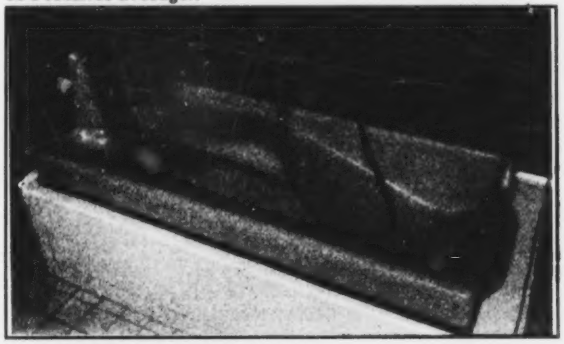

Fig. 4: Siège couvre-baignoire capitonné

Robinetterie: Un mitigeur d'eau thermostatique, avec un levier ou un pousse-bouton, est recommandé pour remplacer la robinetterie existante de la baignoire pour des usagers susceptibles de se brûler.

1.4 Petit siège de baignoire

Ce siège, conçu pour des usagers à mobilité réduite pouvant se glisser du fauteuil roulant, s'encastre dans le sens de la largeur d'une baignoire. Une fois en place, le siège se trouve à la même hauteur que le fauteuil, c'est à dire à 48 cm. La forme de l'assise légèrement inclinée et le dossier du siège stabilisent l'usager et l'empêchent de glisser.

Le siège, réalisé en fibre de verre, est muni d'un système de verrouillage intérieur pour l'empêcher de basculer. De plus, un revêtement souple peut y être appliqué pour éviter les risques de contusion ou d'escarres à l'usager.

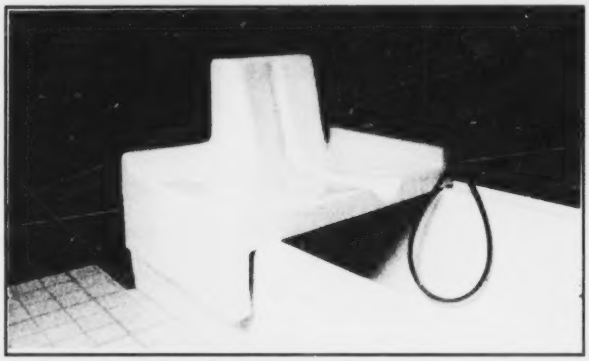

Fig. 5: Petit siège de baignoire

Robinetterie: Un mitigeur d'eau thermostatique, avec un levier ou un pousse-bouton, est recommandé pour remplacer la robinetterie existante de la baignoire pour des usagers susceptibles de se brûler.

1.5 Siège pour baignoire-douche

Ce siège, conçu pour des usagers à mobilité réduite pouvant se glisser du fauteuil roulant, s'encastre dans le sens de la largeur de la cabine et repose sur un piétement qui à la fois recouvre le rebord, et se fixe avec des ventouses au fond de celle-ci. De plus, la forme du piétement permet de glisser un rideau à douche entre le siège et le rebord de la cabine. Une fois en place, le siège se trouve à la même hauteur que le fauteuil, c'est à dire à 48 cm. La forme de l'assise légèrement inclinée et le dossier du siège stabilisent l'usager et l'empêchent de glisser. De plus, le siège réalise en fibre de verre peut être recouvert d'un revêtement souple pour éviter les risques de contusions ou d'escarres.

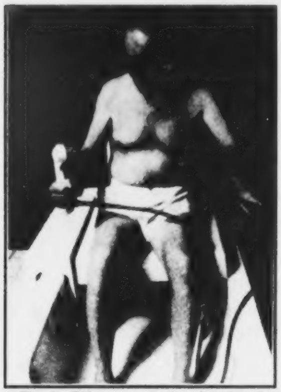

Fig. 6: Siège pour baignoire-douche

Robinetterie: Un mitigeur d'eau thermostatique avec un levier ou un pousse-bouton, est recommandé pour remplacer la robinetterie existante de la cabine pour des usagers susceptibles de se brûler.

1.6 Siège pour cabine de douche

Ce siège, conçu pour des usagers à mobilité réduite pouvant se glisser du fauteuil roulant, s'encastre au mur d'une douche. Une fois en place, le siège se trouve à la même hauteur que le fauteuil. La forme de l'assise légèrement inclinée et le dossier du siège stabilisent l'usager et l'empêchent de glisser. Le siège réalisé en fibre de verre, peut être recouvert d'un revêtement souple pour éviter les risques de contusions ou d'escarres.

Robinetterie: Un mitigeur d'eau thermostatique avec un levier ou un pousse-bouton, est recommandé pour remplacer la robinetterie existante de la cabine pour des usagers susceptibles de se brûler.

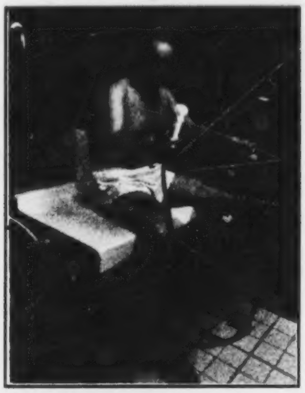

Fig. 7: Siège pour cabine de douche

2. Essais des modèles

Les modèles présentés ci-dessus ont été dans un premier temps essayés par des personnes âgées et à mobilité réduite à l'hôpital du V.A. d'Atlanta. A la suite de quoi une centaine de modèles, actuellement en cours de fabrication, feront l'objet d'essais dans 5 hôpitaux du réseau Veterans Administration, au courant du premier semestre 1988. Ces essais sont effectués, sous la direction du Rehabilitation R&D Evaluation Unit du Veterans Administration, avant la commercialisation des modèles.

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GRADED EXERCISE TESTING AND CONDITIONING FOR THE WHEELCHAIR-BOUND ELDERLY

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Introduction

The essence of aging is an increasing vunerability to all stresses (Shock, 1985). Exercise may be the most powerful intervention currently available for combating the deterioration in functional capacity that occurs with age (Brown & Rose, 1985). Low physical fitness can compound the impact of aging by diminishing the capacity for mobility and activities of daily living (ADL). The loss of mobility decreases the scope of life experiences and diminishes the possibility that an individual will aspire to improve their healthfulness (Tornstam, 1975; Ferrare, 1962). The diminished exercise tolerance of the elderly is as much a result of decreased levels of habitual physical activity as age-related alterations in anatomical and physiological function. The limits of adaptation to the stress of exercise may differ with age, but the capacity to significantly increase exercise capacity in the sixth decade and beyond clearly exists.

Frontera and Evans (1986) have reviewed research designed to study the effects of endurance training on "age-related" changes in physiological functioning. With increasing age changes in lung function include: increased submaximal minute ventilation ($\dot{V}_E$), decreased maximal $\dot{V}_E$, submaximal and maximal ventilatory equivalent ($\dot{V}_E/\dot{V}O2$) are increased; maximum voluntary ventilation (MVV) and % MVV at maximal exercise are decreased. With endurance training submaximal $\dot{V}_E$ and $\dot{V}_E/\dot{V}O2$ decrease, maximal $\dot{V}_E$ and % MVV at maximal exercise increase and MVV is unchanged. Age-related changes in heart and circulatory function include: decreases in maximal heart rate (HR), submaximal and maximal stroke volume (SV), and submaximal and maximal cardiac output; at submaximal exertion HR increases. In endurance trained subjects maximal HR, maximal and submaximal cardiac output are unchanged; whereas, submaximal and maximal SV increase and submaximal HR decreases. Up to 80 years of age blood volume is unchanged, but increases with endurance training. Hemoglobin concentration is unchanged with age and is not influenced by training. The affects of aging on muscle metabolism are: the difference between the oxygen content of arterial and mixed venous blood (a-$\bar{v}_{O_2}$) during submaximal exertion increases, and decreases during maximum work; lactate accumulation increases during submaximal exertion; capillary supply and oxidative enzymes are unchanged. After endurance training, submaximal a-$\bar{v}_{O2}$ difference is unchanged, a-$\bar{v}_{O2}$ difference during maximal effort increases, oxidative enzymes increase, lactate accumulation at submaximal effort decreases and capillary supply is unchanged. There are little or no age-related changes in oxygen uptake at submaximal levels of exertion either before or after endurance training. However, maximal oxygen uptake, a measure of the integrated physiological response to exercise, decreases with age yet is significantly increased with low intensity and/or high intensity endurance training (Badenhop, Cleary, Schaal, Fox, & Bartels, 1983; Seals, Hagberg, Hurley, Ehsani, & Hollosz, 1984; Thomas, Cunningham, Rechnitzer, Donner, & Howard, 1985). The empirical evidence that support the position that endurance training can modify and reverse some age-related changes and slow the rate of decline in functional aerobic capacity continues to grow. This information becomes increasingly important as the health care professional is confronting by a rapidly increasing heterogeneous elderly population.

Thomas and his colleagues (1985) in a study to determine the factors responsible for a training response in 88 elderly men, found significant increases in the aerobic fitness of their subjects after one year. Post training maximum oxygen uptake was significantly associated with pre training values and explained 44% of the total variance, speed of walking or running during training, and reason for stopping the treadmill test explained 10.4% and 2.4% respectively. The only other factor that was significantly related to aerobic exercise capacity was the sum of skinfold measures. It is important to note that subjects who discontinued the initial treadmill test for health related reasons showed significantly less improvement than those who stopped the first test because of fatigue. The findings of this investigation emphasize the importance of the information gained from a reliable and valid initial exercise tolerance test in designing appropriate aerobic conditioning programs for elderly persons, and development of strategies to reduce recidivism.

There are numerous factors which are unique to manual wheelchair locomotion that impose significant physiological and psychological stress on the person who must use a wheelchair to travel. Some of these factors include: a) user's disability, body weight, and skill; b) loss of physical fitness from significant decreases in daily activity, c) inefficiency of biomechanics employed in wheelchair propulsion, d) locomotive velocity, grade, composition and condition of the surface of the route traveled; and e) architectural barriers. Thus, wheelchair locomotion even under ideal environmental conditions can result in elevated levels of exertion and fatigue. For some elderly persons, and patients with cardiovascular and/or pulmonary impairments manual wheelchair locomotion may pose a significant health risk. Health care professionals must make judgments regarding a patient's capacity to endure the exertional stress of operating a manual wheelchair, give exercise prescriptions for rehabilitation and/or develop aerobic conditioning regimens therefore, they must have appropriate measurement tools for patient evaluation.

Research In Progress

At present the vast majority of investigations designed to identify the factors that affect the exercise tolerance of the elderly have employed leg exercise. Researchers have expressed a need for the a standardized protocol and instrumentation for upper body graded exercise testing. The development of appropriate exercise stress testing alternatives for the wheelchair bound elderly is a relatively neglected aspect of exercise physiology. Our purpose has been to develop improved methods for objective evaluation of the cardiorespiratory health and fitness of spinal cord injured (SCI) and other patients with lower limb disabilities. In addition, these evaluation procedures will provide baseline data useful in judging the effectiveness of patient rehabilitation and cardiorespiratory training programs, as well in charting any progressive deterioration of health resulting from disability imposed inactivity. The overall objectives of our research are to: 1) establish standardized maximal and submaximal wheelchair graded exercise tests to accurately measure the cardiorespiratory fitness of patients who are restricted to the manual wheelchair, 2) evaluate the sensitivity of the testing system for detecting abnormal cardiovascular and pulmonary responses to exercise stress in SCI and other persons with lower limb disabilities, and 3) compare wheelchair experimental testing protocol test data against data obtained from conventional arm crank ergometry.

To accomplish the objectives of this proposed research project a prototype device called the Wheelchair Aerobic Fitness Trainer (WAFT) has been constructed and undergone pilot testing at the Rehabilitation, Research, & Development Center, Edward Hines, Jr. Veterans Administration Hospital, Hines, Illinois (Langbein, et al., 1987). This device enables the patient to use his or her own wheelchair as a means of exercise. Graded exercise testing on the WAFT can give a more realistic evaluation of a patient's functional capacity for wheelchair locomotion than alternative modes of exercise. The exercise stress test protocols to be utilized in this research project were explicitly created for the WAFT. The concept of task specificity as applied to wheelchair locomotion has been of paramount importance in the development of both the testing device and the graded exercise test protocols. The new experimental graded exercise test protocols are analogous to well established procedures for lower limb exercise testing, ie., bicycle ergometer, treadmill. Because the intensity of exercise on the WAFT can be controlled it is possible to test patients with very low to very high exercise tolerance. The WAFT graded exercise protocols to be evaluated are: a) submaximal, b) maximal discontinuous, c) maximal continuous. Exercise tests administered on the WAFT, in accordance with established protocols, can provide valid and clinically useful information regarding the locomotor performance capacity and cardiorespiratory fitness of young and old SCI patients and others with lower limb disabilities, as well as the wheelchair bound elderly.

The research design, methods and progress to date that are specific to the elderly participants will be presented at the 11th Annual RESNA Conference.

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POTENTIAL AND REALITY OF COMPUTER TECHNOLOGY IN NORTH AMERICAN SCHOOLS

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Technology, aside from the potential it holds for increased independence and learning opportunities for disabled students, is an important and expanding feature of modern society affecting education, employment and leisure activity. The term "technological applications in education" usually evokes the image of a microcomputer though it includes other technologies such as the calculator, videotape, laser videodisc, microprocesser-based devices such as electronic braille, and satellite communication. The microcomputer, however, is the major tool of the information age. The purpose of this paper is to paint a picture of computer usage in public school special eduation programs in the United States and Canada today. Special educators across North America were informally interviewed by telephone. The paper highlights examples of the most innovative devices and exemplary support systems in use in schools. These demonstrate the enormous potential of computer technology to circumvent disability which interferes with learning. Yet the reality is, technology is scarce in schools at large and few supports exist to nurture its use. Moreover, future special educators are not being acquainted with the tools of the information age. In conclusion, a look to the future expresses the possibility that technology may not be allowed to deliver on its potential to close the gap in educational opportunity for the disabled but will set them farther apart from their contemporaries.

The Potenial: Applications for Disabled Learners

For many physically disabled students, a microcomputer can be a means of communicating, interacting and learning without the assistance of another person or without reliance on a specialized symbol system known by few people (e.g., braille or morse code). For mildly disabled students whose most prevalent deficit is reading, a microcomputer offers infinitely patient practice opportunity, immediate feedback, and graphic oriented instruction. The notable developments in computer technology that benefit these students are alternative inputs to keyboard entry, talking programs, graphics over text as the communication medium, ability to easily program lessons or tutorials, and commercial availability of switches, hardware and software even for severely disabled learners. As much of this originated for business or industrial application, the technology is widely available at lower unit cost.

Examples of Input Devices.

Most software is written with the assumption the user will enter information through the keyboard. Students with limited or erratic motor control may not be able to use even a guarded keyboard. Expanded keyboards, such as the Unicorn, allow direct selection of larger "keys". Twice the size of the Apple keyboard, its flat surface can be programmed in sections varying from one inch square to about ten inches square. The computer accepts ASCII characters from this and other keyboard emulators as if they were keystrokes on the keyboard. ASCII, the American Standard Code for Information Exchange, is used by most computers. Expressive communication aids such as Touch Talker and Express 3 can also enter data in this way. Using the Wireless Data System, a student in a wheelchair can enter data into a computer without wires, i.e., transmit ASCII characters over distance with no physical connection to it.

For students incapable of any direct selection, the Adaptive Firmware Card (for Apple computers) and the PC A.I.D. (for IBM and Compatibles) makes data entry possible with a single or dual switch employing scanning techniques or morse code. This hardware represents a breakthrough in computer applications for severely disabled students by allowing commercially available software to be customized for their use. The customization possibilities are numerous.

Non-keyboard inputs, such as the mouse, touch screen, and voice activation are trickling into education. With the mouse, a student points an arrow at a picture or text with a moveable, handheld box and pushes a button on it to enter data. The Headmaster essentially is a mouse on a student's head which frees the hands. EyeTalker is a communication system which, when interfaced with a computer, enters data from eye contact on eye-gaze sensor positions. Glance of the eye selects a word, phrase or symbol. With Touch Window, the student simply touches the screen to interact with the computer. In a flat position on a table, it can also be an expanded keyboard. Used with Talking Picture Series software, the words chosen are spoken by the computer and a corresponding picture appears on the monitor. With graphics software, students create their own pictures. Still in the experimental stage, full voice recognition is a decade away. Voice activation in structured formats, however, is already in use. One application is taking warehouse inventory. A vocational program for disabled youths will soon use it for jobs which require data from handwritten forms. The information from the forms will be read aloud for data entry. It is expected that even imperfect speech can be recognized by this computer from Kurzweil Applied Intelligence.

Examples of Output Devices.

Talking programs used with speech synthesizers (e.g., Echo) are relatively common although the robotic speech may be hard to understand. Clearly understandable male, female, and even child voices are appearing in the newest software. Key Talk is a beginning word processing program with speech output of letters, words, and sentences in addition to large letters on the screen. The Talking Scanner allows creation and use of customized scanning arrays that talk. Students who use braille may choose from several talking programs, (e.g., Braille Talk and Appleworks with Speech) and on the Ohtsuki printer produce braille with a print translation under it. Raised graphics such as maps, charts, and drawings can also be made on continuous feed or single sheet paper.

Computer Capability.

Macintosh has pioneered an important development which stands to benefit all children barred from mainstream education where the bulk of the instructional load is placed on reading, writing and understanding textural materials. This development is primary use of graphic oriented interaction without use of keyboard input. In development stages but already piloted in schools, ISGraph and HyperCard demonstrate the potential for these disabled learners. Slocum and White at the University of Washington are creating software for the Macintosh. The courseware shell called ISGraph for Instructional System for Graphic Facts contains the code for tutorial and practice sessions but is devoid of specific content. A separate authoring system will create curricular material and integrate it into the shell. They will design graphics programs using this shell for mainstreaming students into science and social studies classes. At Vanderbilt University, Hasselbring is using HyperCard, the sophisticated new software for Macintosh which provides a way to collect, organize and explore information associatively, as we do in our minds. In other words, one can interrupt a learning sequence to explore a related subject or some aspect in more detail. An educator can create personal software with interactive multimedia presentations for group lessons or tutorials without programming knowledge. Teaching about the history of transportation illustrates. The teacher enters a variety of information is organized on "cards" in a "stack" through which a student can move depending on what is of interest. Cards may have text and graphics or can locate and play sequences from a videodisc. For example, you might start with the Wright brothers first flight and link to related topics--films of early flights, a short biography, or a closer look at the lightweight engine. To create an interactive tutorial, questions are merely added to the cards. Depending on their answers, students are guided to different images. Hasselbring is using HyperCard to develop curricular content from upper elementary to senior high for learning disabled students to participate in the mainstream.

The Reality: Technology in Most Schools

Infatuated with the potential and the need to prepare students for the information age, schools have rapidly increased purchases of computers. It is a mixed scene, however, depending on the state or province, the school district and the school. Many have nothing. Some have exceptional programs. Most have bits and pieces--hardware with no software, equipment but no training programs, devices and creative teachers but no support personnel, poor allocation of equipment. Adequate funding for technology is a serious problem in many areas. State and local guidelines and, in some cases, mandates for computer literary curriculum have failed to include special education students so that limited equipment is prioritized away from special education. Rigid administrative decisions have inadvently excluded some disabled students by placing all equipment in labs and no classrooms. Funding must go beyond mere purchase of devices to include support for, or actual development of, programs and curriucula in which to implement the devices. In fact, comprehensive service delivery systems are practically non-existent. The Minneapolis School District is a model, however, with an impressive program in regular and special education. Well planned and executed, it began with specific learning objectives in computer literary for all staff and students with sufficient financial resources for equipment, training, and full-time support personnel. Special education has additional learning objectives and budgets. A clearly defined process for assessment of special technological needs is followed to allocate equipment. The variety of options that exist in funding sources, equipment, software, and allocation of resources, makes it a highly flexible, and therefore, servicable system.

Not since the invention of the printing press has a technological advance held such educational potential as the microcomputer. Today school classrooms look very similar to classrooms of the early 1900's and employ the same tools for learning--chalkboards, pencils, and books. Business offices and factories, however, are hardly recognizable from what existed then. Technology has changed the workplace. Our schools are changing, slowly but surely, so tomorrow's workers will be prepared for this technological mileu. Curricula to assure computer literacy is beginning to be implemented. Computers and related technology are taking the place of the chalkboards, pencils and books. Even primary students are exploring computer applications like word processing, data bases, content software, programming languages, and graphic arts. The goal for technology in special education has been to close the gap between disabled learners and their contemporaries in schools as they have been. If disabled learners are to take their place in modern society, it is essential that they, too, become computer-literate as well. Teacher training is prerequisite to this. Yet results from a survey sent to all 697 special education teacher training programs in the United States shows that little is being done to prepare future teachers. It appears that teacher educators are creating a technology gap at the very time they should be leading the effort to explore the potential of new technologies. Nor is inservice training or incentive pay to take courses filling this gap. On a more positive note, teachers everywhere are struggling to overcome feelings of intimidation about use of technology. They are "begging, borrowing and sharing" equipment, reading newsletters and books, attending conferences and courses, and joining computer networks for teachers of the disabled to learn and to implement as much as they can. Parents, legislators, and business people are beginning to take an interest in education that has not existed since the 1950's when Russia threatened to surpass the West in scientific achievement by placing the first spaceship in orbit. With this support, there is a good possibility adequate funding may become available. We must assure that plans made for federal, state and local monies include disabled learners.

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EDUCATION WITH HIGH TECHNOLOGY - STATE OF THE ART IN SWEDEN

by Karin Paulsson

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Education of children with diabilities does not start at school-age. It starts much earlier. It is important that children with disabilities get a chance to develop along the same lines as other children. To do this they need some help to tear down barriers and obstacles in their way. Help can be given by persons (parents, teachers, doctors, OT:s, etc) technical aids and adapted environments. If we give disabled children some tools for development, nature and the children themselves will take care of the rest. Some of the most important "tools" from early childhood and all the way through life are:

- mobility
- communication
- initiative, curiosity
- motivation
- self-confidence.

These "tools" open up almost all gates to further development. We know from many research projects (Paulsson, 1980, Butler, 1983) that independent mobility for physically disabled pre-school children means a lot to their overall development. And nobody doubts the importance of communication for development of psychological, social and intellectual skills. By analyzing the results from research made by many scientists, Purkey (1970)found that selfconfidence of pre-school children was a better indicator of later school success than scores on intelligence tests. I want to stress this kind of information to make you aware of the intrinsic relationship between body, mind and technology. I could talk about this for hours, but today I will concentrate more on hardware.

MOBILITY DEVICES

Our project on the importance of independent mobility for physically disabled pre-school children (1980) and another project with the purpose to evaluate the total technical aid situation for disabled children (Paulsson et al, 1979) made people in Sweden aware of the fact that technical devices should not be seen as "the last chance" when physical training had not given the results hoped for. Technology could be something positive and stimulating for the overall development of the children. The existing devices, though, were not exciting. Now things started to happen. Lots of resources were spent (by government and private companies) to develop nice and functional devices that were made to suit the needs and wants of children. Earlier the aids had often been small copies of models for grown-ups and often they were made by engineers without any knowledge about children. From 1980 teamwork between engineers, designers, doctors, occupational therapists, physiotherapists and psychologists become more common in technical research projects. During the following years special attention was paid to mobility devices. I will show you some examples:

- COMFORT MICRO,(by Boden Rehab) powered wheelchair for indoor use, ages 3-8 years
- GOCART 80 (by Elektronikservice) powered gocart for outdoor use, ages 4-10 years.
- MIN-IOR (by Permobil) micro computerized wheelchair for indoor and outdoor use, ages 4-12 years.

(All chairs can be manoevered by joy-stick, foot, suck-and-blow etc)

- PERMOBIL MIN-IOR, in combination with an optical sling can be driven by mentally retarded children. The sling is made of reflex tape that can easily be fixed on the floor in different "routes". Photocells on the front of the chair send and receive the light reflected from the reflex tape.
- POWERED STANDING DEVICE made for a small girl with severe muscular atrophy. Hopefully it will come in production later.
- MOSQUITO and KNOTS (by Mölnlycke) are active, light-weight chairs for the smallest children 1-5 years.

As you can see on the film, we provide independent mobility to the children very early in life. We know it is extremely important!

HIGH-TECH COMMUNICATION DEVICES

Research and developmental work in this field is very international and Swedish scientists work together with collegues from all over the world. The collaboration between Sweden, Canada and USA is intimate. Since Janice Light in her paper is presenting almost everything that is worth knowing about augmentative communication, I will concentrate on some products developped and used in Sweden.

Bliss Talk: Bliss Talk 500 S is an electronic Bliss Board with scanning selection of the desired symbols and a built-in speech module. It is made for nonvocal students who communicate with Bliss. It is delivered with the Standard Bliss-chart but is easily reprogrammable. Bliss Talk can be connected to external equipment like computers, other Bliss Boards, earphones, printer or modem.

For students who are spastic and/or have severely reduced mobility this scanning model is the best. There is another version, Bliss Talk 500 D, for students with good coordination. It is operated by a magnetic pointer. Both models are designed to be portable and are normally used as wheelchair lap-trays. All functions are built-in. Joystick, single switches, "sip-and- puff" and other controls are available.

The speech module, Infovox SA201, reads out each word and after a while, the whole sentence grammatically correct. Different voice characters, speech rates, volumes etc can be choosen. With the Bliss Talk nonvocal students can communicate with persons who are not familiar with Bliss. To be able to talk vocally and to everyone means a real "kick" to the selfconfidence of the children.

Bliss Talk 500 S and D can also be used together with the Omni Bliss 1400, a computer program for Apple II+ and IIe, for display of Bliss-symbols graphically on a monitor screen and printout on paper. Both Bliss Talk and Omni Bliss are developped in collaboration between the Royal Institute of Technology in Stockholm, Chalmer's Technical University in Gothenburg, Datatjänst in Lund, Infovox in Solna and Rehabmodul. The speech-synthesizer is developped by engineers at the Royal Institute of Technology, Department of Speech Communication and Music Acoustics in collaboration with Infovox and well-known speech laboratories in several countries.

Multi Talk: Infovox speech synthesizer and an Epson computer with keyboard and printer can be delivered very neatly in an attaché case. This portable and battery operated device is called Multi-Talk. It speaks American, English, French, Spanish, Italian, German, Swedish and Norwegian. There are four voice selections: normal male, dark male, female and child (very light). Furthermore it is possible to control speech rate, pitch level, pitch variation (from monotone to very expressive voice), intonation, aspiration etc.

Alfa Writer: The Alfa Writer is a wheelchair-adapted system that can be installed on Permobil wheelchairs. It is designed for persons having difficulties using an ordinary keyboard. It is operated by the same joystick that is used for driving the wheelchair. Characters can be selected by different methods.

- ° Alpha Standard: A cursor is moved along the sequence of letters displayed on the wheelchair screen.
- ° Alpha Sol 4: Desired letters are selected by tilting the joystick in four different directions.
- ° Alpha Sol 8: Eight directions or "sunbeams" instead of four.
- ° Alpha Super: Characters are selected by "suck-and-blow".

The text can be displayed on the wheelchair screen (up to 80 characters) or transmitted via a wireless Comlink (built into the chair) to a microcomputer or a terminal on a nearby table. The Alfa system can also be used for voice output by a speech synthesizer (also built into the chair).

ELECTRONIC MAILBOX

Margita Lundman, psychologist, and Magnus Magnusson, speech pathologist, both working at the Institute for the Handicapped, are soon finishing an exciting research project called "KOM IGEN" ("Come On" in English translation). Last spring they started a study on electronic mailbox communication for physically disabled young people with severe speech impairments. The aim of the project is to analyse how a computer conference system is used and experienced by a group of sixteen persons, 14-24 years of age, who are more or less nonvocal and have severe motor handicaps. Two of them are also hard of hearing. They all live in different parts of Sweden.

The computer conference chosen is called "KOM". It is available for the public and used regularly by about 2.000 persons. The disabled persons in the project are using KOM as members of a mailbox. By personal computers or text telephones they are sending "letters" and messages to each other and other persons. Sitting at home in quiet they write messages and after that they send them in seconds via telecommunication. They write and read messages when they feel inspired and have the time. The text is stored in the KOM system until next person wants to read and comment on it. After 8 months, 2/3 of the project time, the young persons had created about 1.000 messages (personal "letters" and comments in open KOM-meetings). The texts in the open meetings deals with several topics,

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for example music, sports, films, foreign languages, technical aids and filosophical thoughts.

The assessment of KOM IGEN is very positive. The contact with the other persons of the project is regarded as the most valuable. The young members are now arranging a meeting somewhere in Sweden. They have also decided to write a book together, using the KOM-system as a medium for their collecitve creating. It will be a book about love, happiness and sorrows, attitudes and many other matters.

This project has shown that an electronic mailbox can offer new and extra ways of communication for persons with severe communication disorders. It can be a way to socialize with friends, to share experiences and to find out information. Some have also used it for ordering material they want to buy or for interviews by journalists.

"HEMLIGA HUGO" ("SECRET HUGO")

The "KOM-IGEN" project has inspired others to start similar trials with electronic mailboxes. In Örebro, for example, teenagers with all kinds of communication handicaps take part. Anna who cannot speak, Bosse who is deaf, Carina who can neither speak nor hear, Erika who is blind are some teenagers mentioned by Christer Söderbäck in an article on computers in special education. Thanks to "Hemliga Hugo", the computer, these teenagers can have a conversation. Anna has an old black Text telephone, Bosse has a brand new Diatext II (text telephone), Carina has a Compis computer with a joy-stick operated communication program plus a telephone modem and Erica has a versa-Braille and a modem. This electronic mailbox was originally made for deaf students with text telephones but now callers using all kinds of computerized equipment have access to "Hemliga Hugo".

ENVIRONMENTAL CONTROL

Let us go and see Helena, a 23 year old woman living in a fully adapted flat of her own in Stockholm. Helena has cerebral palsy of athetoid type. She has big problems to make herself understood by speech but she is a bright girl who was individually integrated in compulsary school and college. After studies on computers, (at a special folk high-school education on computers for disabled students), she is now working at a museum making files on all items displayed there.

Helena lives a very active life with job, family, boy friend, other friends and her social life includes horseriding, pop music, opera visits etc. Thanks to technology Helena is very independent.

Helena drives a Permobil IOR. With the joystick of the wheelchair she can control a lot in her everyday life. The wheelchair is provided with a so called communication link, or comlink. It is an IR-system for remote control of a variety of equipment, for example opening doors, turning on the light and operating the controls of a TV-set or a radio. With the comlink it is also possible to make telephone calls and switch on a computer, all without wires.

All parts of this equipment are marketed by GEWA and Rehabteknik. All functions are operated by the joy-stick of the chair. The standard steering functions are switched off by pressing a button on the control panel, and after a "click" sound the comlink system can be activated.

But Helena is only using high-tech when it is the best of solutions. When she talks she often needs support from a "technical device" to be understood. Then she chooses to use a simple hardboard chart with letters and common small words like "I", "her", "and" etc. With this chart, that is specially made for her according to her own personal needs and wants, she can converse much faster than with a speech-synthesizer.

COMPUTERS AS EDUCATIONAL TOOLS

Just as in Canada and USA we have great expectations on computers as educational tools in school. We share the same hopes and we have the same stones on the road. The picture Charlene Butler is painting of North America is very like that of Sweden. I will tell you a little about what we do to get experiences and build up a well working system for the future. Sweden has a close collaboration with USA and Canada and to a high degree we are using the same kind of computer hardware. Quite often we also use the same software but translated into Swedish.

For a few years The Swedish Institute for Teaching Material (SIL) in collaboration with the Institute for the Handicapped (HI) and in close contact with the Computer Program Group at the Ministry of Education have been working on a project for development of programs that can be used in the education of students with physical or sensory losses. The aims are to build up a national basis for production and selling of program products for handicapped students, to initiate development, adaptation and evaluation of program products and to initiate and support special training for teachers and other persons involved etc. Projectleaders are Ulla Barthelson, SIL, and Hans Hammarlund, HI. At SIL there are four units called National Centres for Educational Aids, (one for physically disabled students, one for blind students, one for deaf and hard of hearing students and one for mentally retarded students). These centres, that each have resources of their own, are responsible for sub-projects starting within the project. They collaborate with institutions, resource centres, local schools and technical aid centres in the counties. The methodology used in the sub-projects has been very similar. First a solid base of knowledge was built up and for each handicap field the needs were invented, education plans were analysed and demand specifications were made (for hardware as well as for software). Then the supply of Swedish and international computer programs was invented and adapted. Now they have started developmental projects based on the needs for each handicap group.

Here are some examples of programs:

- Tomteboda Resource Center (earlier a special school for blind children) together with the National Center for Educational Aids for the blind and a private company have finished a project for students with low vision. To make it possible for these children to work with a computer program often used by other students in Swedish schools, the text on the computer screen is transformed into synthetic speech and/or extra large text. Tomteboda is now working hard to make the computer equipment and programs accessible to students who are blind or have low vision.
- TV, film and video are important sources of information for all children, also for those with intellectual handicaps. But maybe the latter group needs extra training to understand the complex "grammar" of the film language, just as they need extra training in reading? An interesting project on this is started by Manne Lidén, at the National Center for Educational Aids for Mentally Retarded.
- In Sweden there are also plans to build up a few regional resource centers for computerized aids. The center should give advice and practical help to the schools, give special training to teachers and students. It is also planned that research and developmental work will take place at the centers.

DO STUDENTS GET THE TECHNICAL AIDS THEY NEED?

A basic principle in Sweden is that all persons with all kinds of disabilities should receive all the technical aids they need free of charge (without the application of a means test). Most aids are provided by the county councils via technical aid centrals or persons with special authority to make prescriptions. In theory people can have everything they need. In practice it is not always so. In bad times the county councils make restrictions, for instance on very expensive devices like computers. Sometimes lack of knowledge by the prescribers leads to lack of aids for the disabled persons. Lacking information to the consumers also means that they often can not ask for things that could be of value. The follow-up of persons with progressive diseases is sometimes missing etc. But even if the system is far from perfect, I am convinced that it is much better than in most other countries. In 1968 100 million Swedish Crowns were spent on technical aids. The figure for 1988 is estimated to 2 billion Crowns.

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AUGMENTATIVE COMMUNICATION: STATE OF THE ART IN NORTH AMERICA

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INTRODUCTION

In today's society, communication between individuals occurs through three main channels:

1. face to face communication in which the participants are in the same place at the same time;
2. written communication in which the participants may communicate from different places, at different times; and
3. telephone communication in which the participants may communicate from different places, but within the same time frame (1).

For the individual, who is physically disabled and is unable to speak or write, access to each of these three channels of communication is severely restricted. It is the challenge of clinicians and technical personnel in the field of augmentative communication to develop systems of communication to allow individuals, who are unable to speak or write, the means to fully participate through each of these channels. While telecommunication is critical in meeting vocational, daily living, and personal communication needs, it is beyond the scope of this paper to deal with this area. Rather, the focus of the paper is on the face to face and written communication needs of physically disabled students who use augmentative systems. Within these two areas, the paper outlines needs, applications of technology to meet these needs, state of the art in technology, current research and development activities, and critical issues for future research and development. Of necessity, this paper can provide nothing more than an overview of the central points in each of these areas.

FACE TO FACE COMMUNICATION

There are four broad communication needs to be fulfilled in communicative interaction: expressing needs and wants, exchanging information, developing social closeness and personal relationships, and conforming to social etiquette routines (2). These needs may take on varying degrees of importance over the course of an individual's lifetime, depending on the environment and life style choices (2,3). Moreover, each of these needs dictates different requirements for communication systems, relative to their intelligibility, rate, flexibility of content, and independence required by the user (2,4). Given these different requirements, it is not surprising that, for individuals using augmentative systems, communicative interaction is essentially multimodal (5,6). The actual modes or systems used in interaction depend on the partner, the context, and the intent of the message. It is doubtful that technology will ever fulfill all communication needs. Thus, technology should not be viewed as a panacea, but rather as one more powerful tool which may potentially contribute to overcoming communication restrictions in face to face interaction. To date, the technical developments in augmentative communication have primarily addressed the needs to exchange information and express needs and wants (2). Yet, we must not lose sight of the need for systems of communication which allow physically disabled individuals to develop social closeness and just "hang around" with friends, for this need is one of the most fundamental to the human experience. It is especially evident for children and adolescents in their school years as they interact with peers and develop a sense of themselves and their belonging to a group.

Applications of technology

The development of portable computer-based communication devices, especially voice output communication aids (VOCAs), has offered the potential for increased functioning by providing access to the following:

1. audible messages to facilitate group interactions and interaction at a distance;
2. "translation" of messages into a common format, mutally understood by the participants (e.g., translation of the messages of an individual, using traditional orthography to communicate, into a spoken format which can be understood by nonreaders);
3. means to communicate emergency needs and wants which might otherwise have been ignored;
4. greater conversational control (e.g., a means to initiate interaction, interrupt conversations, etc.);
5. greater independence for users, especially with unfamiliar partners who may be uncomfortable or unskilled in the process of co-constructing messages which is required if nonelectronic communication displays are used;
6. auditory feedback for the user to support language development, especially at a syntactic level;
7. access to more vocabulary than that which could otherwise be easily targetted or displayed; and
8. potential acceleration of the rate of communication through abbreviation expansion or predictive linguistic techniques.

Computer-based communication devices may also play an important role in the development of the user's self-concept and personality, and in society's perception of the user's competence (2,7). Voice output devices may serve to facilitate the recovery of speech and language functioning for individuals with acquired disorders by cuing the user to the retrieval of words and messages (8). To date, we have largely ignored the impact of communication aids on interaction (9); obviously, this area requires concerted research attention.

Current technology

Fundamental technologies such as nonelectronic communication displays often play a crucial role in meeting the interactional needs of physically disabled individuals, both as primary communication systems in some situations, and as back-up systems in case of the breakdown of more advanced technological devices. Furthermore, fundamental technologies such as appropriate seating systems may be required to ensure that the individual is able to make effective use of the electronic communication device (10). In fact, "many of the problems faced by disabled persons are better solved through the use of fundamental technologies rather than through advanced aids" (10, p. 703). Although this paper focuses on the more advanced technological devices available, the role of fundamental technologies in meeting interactional needs should not be forgotten.

This section briefly describes the portable computer-based communication aids which are currently available in terms of their input and output potential. For more detailed information in this area, readers are referred to Vanderheiden and Lloyd (11).

Input – The input to these devices can be subdivided into considerations related to the selection set and those related to the selection technique. The selection set refers to the items available to the user for selection (12). The set of selectable items can be described in terms of its representation, presentation, and actual content (13). A range of representational systems or symbols can be used within the selection sets of computer-based devices, including pictures, symbols such as Picsyms (14), Blissymbols (15), or Minsymbols (16), and traditional orthography in letters, words, or phrases. The selection set is typically presented in graphic format as characters on a transient display or keyboard overlay. If the user's visual skills are impaired, the selectable items might be presented through an auditory mode as in the case of auditory scanning, or through a tactile mode, as in the case of Braille or other raised symbols. Decisions regarding the presentation of the selection set involve considerations regarding the size of each item, the number of items, and the organization or layout of these items. The actual content or vocabulary should be decided on an individual basis based on the user's needs and skills and environmental characteristics. Increasingly, communication devices are being developed which allow greater flexibility of representation, presentation, and content so that devices can be customized on an individual basis to meet specific user requirements.

A wide range of selection techniques are available to allow individuals to access electronic communication devices. These techniques can be categorized into two main types: direct selection, where the individual directly indicates the desired item; and scanning, where items are presented to the individual one at a time and the user signals when the desired item is presented (11). Direct selection techniques include the selection of keys on a regular keyboard, an expanded keyboard such as the Unicorn™ or King™ Keyboards, a miniature keyboard, or a one-handed keyboard such as the chordic keyboard. Selection may be facilitated through the use of various aids, such as head or chin pointers, or lightbeam pointers which may be attached to the head, hand, arms, or feet. There are a variety of communication aids currently available which allow for a range of direct selection techniques, with various sizes of keyboards, various numbers and sizes of keys or targets, and various configurations or arrangements of these targets.

Direct selection techniques tend to be the simplest and fastest access methods. However, these techniques do require some type of graded motor control (11), and may be outside the skills of some individuals who require augmentative communication systems. For these individuals, scanning techniques provide an alternative means to transmit messages, since with this technique the individual only requires a single consistent and reliable motor act to activate a switch to signal when the desired item is presented. Scanning approaches can be used with a variety of switches, ranging in size, shape, property sensed (e.g., force, change in orientation, motion, or electromyographic signals), and feedback provided, whether auditory, visual, tactile, or kinesthetic.

Many of the available computer-based communication devices offer the processing potential to accelerate the client's rate of communication or to increase the number of items available for selection through various encoding approaches (11). With these techniques, the individual gives multiple signals through direct selection or scanning; these signals are then processed together by the computer to specify a desired item from the user's vocabulary. Morse code is an example of an encoding technique used to increase the number of items available for selection. Acceleration techniques take various forms including abbreviation expansion techniques and linguistic prediction techniques (17). Abbreviation expansion techniques can be used with words, phrases, sentences, or longer text. These larger units are preprogrammed into the aid and represented by a smaller set of keystrokes. The keystrokes or codes used to represent messages may include numeric, alphanumeric, and alphabetic codes, as well as codes based on semantic compaction, in which words or phrases are represented through sequences of icons which are rich in their associations (16). Abbreviation expansion offers the potential to save a considerable number of keystrokes for the user in contexts where messages are largely predictable. However, the full potential of these techniques will only be realized if the cognitive demands to memorize codes are minimized and if the user reaches a sufficient level of proficiency that using the codes is largely automatic and does not require conscious processing (18).

Linguistic prediction techniques include those techniques in which the computer system predicts the next letter or the entire word based on the letters already selected. Word prediction techniques may be based on frequency and/or recency of vocabulary used and may or may not consider grammar as a factor in the prediction. Many linguistic prediction techniques are still under technical development to maximize their efficiency. Furthermore, the clinical implications of these techniques have only begun to be explored. For faster users, it seems that theoretical gains in motor efficiency may be offset by the cognitive and visual perceptual demands of reacting to the changing display (17, 19). Ongoing research is required into the human factors issues involved in these acceleration techniques.

Output – Most computer-based communication devices provide a variety of output modes for users and their audiences: synthesized or digitized speech output, hard copy print output, and output on a transient display. All three types of output may be required depending on the partner, the context, and the intent. In the case of speech output, intelligibility is obviously a major concern. Results of research into the intelligibility of various commercially available speech output systems suggests that for many systems, intelligibility at the sentence level, and especially at the word level, is by far inferior to the intelligiblity of natural speech (20). The DEC Talk™ synthesizer has been found to be consistently closer in intelligiblity to natural speech, but this system is currently very expensive and not easily transportable for face to face communication. Other factors related to speech output such as gender and age appropriateness, voice quality, and prosody are also of critical importance, but these factors have received minimal attention to date.

At present, portable communication devices are restricted to providing hard copy or transient display output in alphanumerics. Output in symbolic or pictographic systems is limited to specific applications on stationary aids. This limitation is especially problematic for the user who is a nonreader and is unable to decipher the feedback to determine if selections of pictures or symbols are accurate.

Selection of the most appropriate communication systems for an individual is a complex process which depends on the user's needs and capabilities (motor, sensory-perceptual, cognitive, and linguistic skills), as well as environmental considerations and constraints (9).

WRITTEN COMMUNICATION

Vanderheiden (1984) has noted that a heavy focus on the conversational needs of individuals who require augmentative communication systems may result in other needs, especially written communication needs, going unnoticed or unmet (21). Such a neglect of written communication needs may result in a serious handicap, since written communication is essential in today's information-based society, especially within educational and vocational environments. Written communication may carry even greater importance for individuals who are unable to speak, since it may provide not only a means to fulfill the conventional functions of writing, but also a means to circumvent some of the limitations experienced in meeting the real-time demands of communication in face to face interaction.

Written communication needs can be categorized into two main types: needs, such as note taking, which must be met with on-the-spot, portable systems; and needs, such as completing homework assignments or writing letters, which may be met through stationary, work station approaches (21). Technology has played an important role in meeting both these needs through the use of portable computer-based devices in the former case and through the application of stationary microcomputer systems with adaptive peripherals in the latter case.

Applications of technology

Applications of technology to meet written communication needs provide access to the following:

1. word processing programs and other computer applications to allow full participation in the educational curriculum or vocational environment;
2. tools for early literacy experiences to support language development;
3. means to take notes in educational, vocational or daily living activities;
4. access to writing for personal expression such as journal writing or artistic expressions such as poetry or drawing;
5. means to maintain interpersonal relationships at a distance through letter writing, thus bypassing the limitation on telecommunications;
6. options for pre-preparing messages to circumvent limitations experienced in face to face communication;
7. access to organizational aids, such as schedules, lists, and topic outlines to assist in daily living activities and educational/vocational pursuits (organizational aids may be especially important for individuals with head injuries who may experience considerable memory and organizational difficulties); and
8. access to therapeutic programs to remediate specific deficits and to improve functional abilities.

Computer technology to meet written communication needs has played a fundamental role in increasing the level of independence realizable by many physically disabled individuals. This increased independence has allowed for more accurate assessment of students' skills within educational programs, since the potentially confounding effects of an assistant are diminished (11). The potential for greater independence has increased vocational possibilities, and may result in a sense of greater self-esteem and the social perception of greater competence.

Current technology

Providing access to a writing tool for physically disabled individuals is not a simple matter. There are a wealth of special adaptations, peripherals, and programs to allow access to microcomputer systems (22). Since portable computer-based systems have already been considered in the section on face to face communication, discussion in this section is limited to stationary microcomputer systems. Through adaptations such as the Adaptive Firmware Card™, the PC AID™, and the MOD Keyboard™, access to personal microcomputer systems is possible through a range of selection techniques, including both direct selection and scanning techniques. As with the portable systems, input can be provided through a variety of devices, including standard or alternate keyboards, lightbeams, joysticks, and single or multiple switch arrays. In addition to these options, systems are currently under development to provide access through eye gaze and speech recognition. In most of the eye gaze systems, a high resolution camera is used in conjunction with computer technology to detect eye movement to various locations to select desired items (23, 24). To date, these systems are very expensive. They require the user to maintain steady head control and are less reliable if used with glasses or contact lens. Speech recognition systems allow an individual to input letters or words by speaking them aloud. The computer system then matches the spoken stimulus to a template and translates it into the written form. At present, these systems accept only a limited range of input. Furthermore, the user may require considerable training. Speech recognition systems offer potential applications for individuals who are able to speak but unable to write. The potential of their application with individuals who have severely dysarthric speech requires further exploration.

As with portable systems, stationary microcomputer systems have been adapted to allow for selection sets of various representations, presentations, and content. The processing capabilities of stationary systems also allow for acceleration techniques such as abbreviation expansion and predictive linguistics. These techniques may have even greater potential in writing systems since in this case the user is only required to attend to the writing process and not to simultaneously monitor the partner as in the case of face to face communication. Many stationary systems utilize participatory logic routines such as spelling or grammar checkers, which may be useful for individuals with limited linguistic skills. The trend in stationary and portable systems is towards systems, such as the Trine System™ or E-Z Keys™, which allow multi-tasking by the user, for example, moving from note taking to conversation and back.

The output on most stationary systems is through the computer monitor or a standard printer. For many individuals, a speech synthesizer may also be provided to provide feedback for the user regarding selections. This feedback may be especially important for individuals who have visual impairments or who use selection techniques such as a headstick which inhibit continual monitoring of the screen. The feedback from a speech synthesizer may support literacy development at spelling, syntactic, and text levels for these individuals as well.

RESEARCH AND DEVELOPMENT

Although the advances in technology to date have increased the options for many individuals who are unable to speak and write, ongoing research and development is required to ensure that the technology is better able to meet the face to face and written communication needs of these individuals. Directions which are currently being explored in the area of research and development include the following:

1. research into innovative approaches to accessing, including the ongoing development of more reliable and efficient eye gaze systems, the exploration of speech recognition with dysarthric individuals, the use of proportional access methods to allow greater control and flexibility for the user, the development of computer standards for manufacturers, and the development of technical specifications to support more universal approaches to accessing to accommodate a full range of user needs and skill levels;
2. research into encoding and acceleration techniques including the development of more efficient approaches to linguistic prediction and the exploration of applications of artificial intelligence;
3. research into a wide range of computer applications and functions, including the development of RAM resident macro programs to allow customization of word processing programs and other applications to meet individual client needs, the development of transient keyboards to facilitate multi-tasking, and the exploration of alternative approaches to communication aids which account for the dynamics and structure of interaction;
4. research into speech output to improve quality and to allow access to a wider range of languages;
5. research into robotics as a means to address some of the ergonomic aspects of computer access; and
6. research into assessment protocols and expert systems to assist clinicians in the complex process of customizing augmentative communication systems to meet individual needs and skills.

FUTURE DIRECTIONS

The application of technology in the field of augmentative communication is still very much in its infancy. Very little is actually known about the impact of communication aids on users, on partners, and on the interaction and writing processes. Future research is required to explore the benefits and difficulties associated with the application of technology.

1. Research should consider the role of fundamental and advanced technologies in meeting interactional needs and written communication needs. It is often erroneously assumed that advanced technologies are "better", and yet this is not always the case. Future research needs to explore the interplay of these options and their relative contributions.
2. Since many physically disabled individuals may require a range of fundamental and advanced technologies to meet their daily living needs, research is required to explore integration of these technologies, both from a technical point of view (i.e., the optimal mounting and positioning of the hardware in relation to the user, to other technologies, and to activities of daily living) and from a functional point of view (i.e., the appropriate and integrated use of various techniques and strategies in the natural environment).
3. Future research should explore the human factors issues (i.e., cognitive, sensory-perceptual, linguistic, and motoric factors) involved in the user-computer interface. Although the application of technology may potentially bypass many physical limitations, it may involve increased cognitive, sensory-perceptual and/or linguistic demands. To date, these areas have received little research attention.
4. Developing the operational skills required to technically operate a computer-based communication system, is not sufficient to ensure its functional use. Rather the client must develop a range of linguistic, social, and strategic competencies to ensure effective use of the system to meet interactional and written communication needs. Research is required to explore the competencies required by users and to identify effective approaches to teaching these skills.
5. The delivery of augmentative communication services requires not only the provision of appropriate technologies, but also client and facilitator training to ensure their effective use. Research is required to explore models of service delivery and their relative effectiveness given various client populations, geographic circumstances, social support networks, and environments.
6. Assessing clients to determine the most appropriate systems to meet their needs given their capabilities, environmental considerations and constraints is a complex process. Research is required to develop valid, reliable, and clinically viable assessment protocols to assist clinicians in this process. There is currently a paucity of trained professionals in the field of augmentative communication. Pre-service and in-service training programs must be developed to ensure that professionals have the skills which they require.
7. Further technical developments are required in the field to meet the needs identified by consumers and clinicians.

Needs which are currently unmet include:

- innovative access methods to accomodate multi-handicapped users, specifically those with sensory and physical impairments;greater simplicity in system design to decrease the 'cost of learning' for clients and facilitators;
- access to standard computer-based equipment;
- greater flexibility in system design to accomodate a range of functions and various access methods;
- strategies to overcome ergonomic factors such as handling paper or disks, or operating direct manipulation devices such as a mouse;
- developments to permit individuals to converse and write at rates which are acceptable in real time;
- improved quality of speech output to accommodate personal features and to allow telephone access;
- multi-lingual speech output; and
- low cost devices which are universally accessible to disabled individuals.

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THE EDUCATION OF PROFESSIONALS AND CONSUMERS IN THE APPROPRIATE SELECTION AND USE OF TECHNOLOGY

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The increased provision of technology to persons with physical disabilities is occuring internationally. The mechanism used to evaluate, provide and train persons in the use of the technology varies widly as does the expertise of the professionals and the level of knowledge of the consumers who are the recipients and sometimes users of the devices. At present there is no one place in North America that provides comprehensive training for professionals to prepare them for the tasks at hand. There is no formalized mechanism, nation wide, for consumers to become knowledgeable as to what technology is available and what might be appropriate for their use. There is no quality assurance body to monitor the competency of staff or programs who are providing technology. A tremendous challenge faces our field as we work toward quality assurance in the provision of technical aids today and in the future.

WHO

Both professionals in the field and on the periphery are in need of mechanism to develop expertise in technology provision. This expertise would include knowledge about what technology is available, which are quality products, where to get them, and how to get them funded. They need to know how to evaluate clients for technology and how to provide the technology including training and followup services. In the ideal situation, the provision of technical aids is done by a team of professionals in discussion with the client but this can even magnify the challenge as we look at the preservice training of the professionals who might be included in the team. At present there is no comprehensive training in the provision of state of the art technology in undergraduate programs in Occupational Therapy or Physical Therapy. Some programs do have a course which provides an overview of technology available and give some selection criteria but none provide internship placements for practical training under the guidence of professional experts in conjunction with a full didactic program. There is presently no accredited program to train rehabilitation engineers. Some biomedical engineering programs provide electives in the area but again there are no full programs for training. Vocational rehabilitation counsellors and teachers who are the professionals who could most often make referrals of students and clients who could benifit from technology often do not know of the value of technology or where to refer for services. The same holds true for physicians, nurses and other primary caregivers in the rehabilitation process.

As well, a dearth of professionals who may not have a full knowledge of available technology, we have a community of children and adults with physical disabilities who do not know that there is technology available that might assist them in their educational, vocational or life goals. What is even more alarming is that they have no assistance in evaluating the compentencies of professionals who might be in a position to guide them towards technical services.

WHAT

What is needed is a comprehensive approach to the education of professionals and consumers. We need a component of training in undergraduate programs so that professionals will at least know where to go for assistance or where to refer their clients. We need a series of inservice training programs for professionals who wish to specialize in the field of technology provision. Sources of information for clients who wish to take an active role in their rehabilitation process must be readily available. There is a critical need for the development of curriculum materials appropriate for professionals and/or consumer groups. Publications on technology related topics in newsletters, journals and books should be encouraged. Audio visual programs should be developed and made available to all who would benifit. Creative training programs with internships should be offered in all areas of technology provision from those programs who have developed areas of expertise. And we must work towards a mechanism of quality assurance or certification which would provide standards that clients and funding agencies could use as criteria for selection of appropriate service delivery professionals or programs.

HOW

RESNA- an Association for the Advancement of Rehabilitation Technology is a logical body to provide guidence for educational activities in the area of rehabilitation technology. It is a multidisciplinary society of professionals interested in a high quality of service provision often in conjunction with research and educational activities. RESNA already holds an annual conference during which scientific and clinical papers are presented. There are preconference instructional courses and morning seminars and exhibits which are open to the public. It publishes proceedings from the conferences and a variety of books on topics related to technologhy. Shortly, in addition to the newsletter published by RESNA, there will be a professional journal available.

It is the challenge of RESNA membership to work towards additional quality educational activities both within university and other formal educational settings and informally at a continuing education level. We must continue to publish results of our clinical and research activities for the benifit of our colleagues and their clients. As funding opportunities for demonstration programs and statewide service delivery models become available we must apply for funding and publish our projects experiences.

WHEN

We must work quickly. Right now there are funding opportunities for demonstration and clinical research projects in the area of rehabilitation technology provision. Legislation is proposed in the United States to establish state wide systems for the delivery of technology to children in special education environments. Rehabilitation Engineering services must now be available to clients receiving vocational rehabilitation services in the U.S.A. In Canada, a provincial network of technical services now exists although in varies considerably from province to province.

We have a challenge to provide quality service and the place to begin is in the education of professionals and consumers. The special session guest speakers to follow will address many of the above issues. We will learn of the delivery system for technology in the province of Ontario, about an education program for Vocational Rehabilitation professionals in the state of Wisconsin, of creative mechanisms to inform consumers in several countries and finally some thoughts as to training of professionals at a preservice level. The session is meant to gererate ideas not to propose specific solutions. So be prepared to take some of the ideas which might be appropriate to your area or the population you serve and then work like mad to incoroporate them into your own plan of action.

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UNDERSTANDING AND INTEGRATING TECHNOLOGY FOR REHABILITATION

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BACKGROUND

Assistive devices are but one tool in the plethora of approaches that might be taken by or for any individual in need of physical (re)habilitation.

In Ontario, the Assistive Devices Program (ADP) has been developed over the past six years to ensure that people needing (re)-habilitation equipment obtain it readily. ADP, a program of the Ministry of Health, has an Advisory Committee which recommends direction, policy and program evaluation.

Such a program must be an integral part of the overall rehabilitation system. As well as addresseing assessment and prescription, it should provide training in the use of devices, follow-up and reassessment for rehabilitation clients. To ensure that only needed and appropriate equipment is prescribed, the prescription must be done as part of a total assessment and treatment process. Practitioners who can reliably define the most appropriate mode of intervention (therapy, medication, equipment, surgery, or various combinations of these) for particular clients are essential for an effective system.

ADP covers 75% of the cost of mobility aids and seating systems; orthoses including body braces and splints, burn and pressure garments; prostheses including prosthetic limbs, and eyes, and breast and facial prostheses; incontinence and ostomy supplies; communication aids for either speaking or writing; hearing aids; respiratory equipment and supplies including ventilators, compressors, suction machines, percussors, drainage boards, and oxygen and its equipment; and visual aids for both sight enhancement and substitution.

Most equipment, once purchased with ADP's assistance, is owned by the client. Certain equipment, such as communication aids, is owned by the designated rehabilitation centre or hospital which in turn leases it to the client.

At predetermined intervals, ADP will help to replace equipment. ADP provides only for one device that performs the same function in each replacement period unless that device is life-saving (e.g. a ventilator). ADP does not cover repairs or maintenance of purchased equipment. To be eligible for ADP coverage an individual must be assessed by health care professionals designated as authorizers for each of the equipment categories. These usually consist of either a team of rehabilitationists, or individual physicians who then make referrals to appropriate therapists, nurses or other rehabilitation personnel. Three basic steps are involved in the process of getting devices: medical certification of client need and readiness (from a holistic perspective), authorization of the specific equipment, and its supply. The policy of the program is that there shall be no potential for conflict of interest between those prescribing and selling.

Early in the development of the program it was recognized that not all health care professionals were equally skilled with the wide and expanding range of rehabilitation devices and with the role of technology in the rehabilitation process. Nor were all members of each profession necessarily equal in these matters. Mistakes would be costly to the Ministry and hence the taxpayer, and would cause at least a delay in the rehabilitation process and if more serious, harm to the client. The Advisory Committee recommended that only individuals demonstrating up-to-date knowledge and skill in particular areas become authorizers for related devices.

Providing services through multi-disciplinary teams is recognized as an effective way of delivering high quality service.

The Advisory Committee on Assistive Devices and its subcommittees have developed a set of characteristics that they believe are essential for those prescribing rehabilitation technology:

- a thorough knowledge of general rehabilitation and the specifics relevant to the area of specialization;
- skills in general assessment including an ability to integrate client perspectives;
- a good knowledge of prognoses of diseases or conditions affecting the population in need of rehabilitation to allow, for example, anticipation of quickly changing needs;
- a good working knowledge of relevant equipment, its characteristics and any contra-indications;

- an ability for, and interest in, keeping up with new developments in technology; and

- an ability to assist clients to learn safe, appropriate use of equipment.

EDUCATION

A number of initiatives are in place or are being developed to ensure that health practitioners have the characteristics indicated above.

ADP has set basic criteria for those who will be prescribing devices on behalf of the program. Once candidates are approved they must then attend an orientation workshop designed to familiarize them with ADP while giving them up-to-date information on the particular category of devices of concern. These workshops which include material on assessment, selection of equipment to meet client needs, client training and follow-up techniques, are given by ADP staff in combination with provincial and local specialists in that field.

The recognition of the paucity of appropriately trained personnel was a major factor, along with the reality of limited financial support, that prompted the consideration of multiple levels of service. Tri-level systems form the basis of the Ontario health system and that model was therefore thought to be an appropriate one upon which to build. In this model, tertiary level clinics (associated with teaching centres) have responsibility for formal and informal teaching. The Augmentative Communication Service of Hugh MacMillan Medical Centre, for example, has been conducting internship programs for several years.

A further feature of the tri-level clinic system is the fostering of networks among clinics and individuals. Now, primary level clinics are forming relationships with one or more comprehensive clinics for the purposes of obtaining advice; for the loan of more specialized devices; and being kept up to date with major developments in the field. Similar relationships are being developed between solo practitioners and general clinics.

Another initiative beginning in 1988, will have a significant impact on the skills and knowledge of practitioners and consumers. The Rehabilitation Technology Development Program will support teams of researchers linked with Health Science Centres and their affiliated clinics which provide formal training to health professionals, and other universities and hospitals. It will also fund time-limited individual research or development projects. To ensure the ongoing development of trained researchers and clinicians, scientists supported by this new program will be expected to supervise students, and train service providers including rehabilitation engineers.

It will include a program of workshops, conferences, visitors and outreach instruction for consumers, health practitioners, manufacturers and vendors. Particular effort will be given to teach assessment, training and evaluation techniques to front line practitioners in their community settings. The evaluation component will emphasize methods and use of cost-benefit analyses. Attention will also be given to the development of tools to assist in appropriate matching of client needs with available devices.

The program will also include development of curricula for undergraduate and graduate study, support of graduate students and fellows to investigate, develop and refine techniques, and create new systems and devices. A coordinated inter-university approach is to be promoted to identify existing teaching resources, and facilitate new educational programs to be available on a province-wide basis.

FUTURE NEEDS

While a variety of educational opportunities are available for consumers, a comprehensive catalogue of devices providing cost-benefit analyses is needed. Various technologies, such as compact discs, which hold great promise for information dissemination and updating are now being developed. Integrating technology in the overall rehabilitation process through multidisciplinary teams including consumers with appropriate background and education will lead to significant enhancement of client needs.

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Training Vocational Rehabilitation Staff in the Use and Application of Rehabilitation Technology

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ABSTRACT

There is a strong need for training of service delivery personnel within the vocational rehabilitation in use and application of rehabilitation technology. Training should address both immediate and long term needs. A strategy of offering a regional, phased model of field based training workshops follow-up by options of clinical affiliations, conferences and long term training is presented. Major issues for delivering training are also identified.

INTRODUCTION

Rehabilitation (engineering) technology services have been provided to some degree by state vocational rehabilitation agencies and rehabilitation facilities for approximately twenty years. What has changed significantly in the past several years is the scope and nature of technology available for assisting persons with disabilities and the environment in which these rehabilitation services are provided (1).

Mandate for Services

For the VR agencies the Rehabilitation Act Amendments of 1986 provided a strong mandate for the delivery of rehabilitation engineering services. This marked the first time that rehabilitation (engineering) technology services have been specifically cited in the authorizing legislation for VR services.(2)
The provision of rehabilitation technology services is not simply providing a technical aid or device to solve a problem. The delivery of rehabilitation technology services should ideally be provided in a multidisciplinary, professional environment which can provide the support and resources necessary to meet the complex needs of individuals with severe disabilities.(5)

Need for Training

Results of a national survey of rehabilitation technology utilization in state vocational rehabilitation agencies clearly indicates the need for training of VR professionals in the area of rehabilitation technology resources and services.(1) A priority ranking of critical needs placed training as the most important issue faced. Estimates on the amount of training that rehabilitation agency staff have received were very low. The sources of training for vocational rehabilitation agencies tended to primarily be from agency in-service and professional conferences. These two approaches for providing training, while being beneficial, tend to be very general and lack well coordinated goals and objectives and any specific training plan.

Within the vocational rehabilitation system of delivering services, responsibility rests primarily with the field based counselor to determine vocational goals and objectives, services to be utilized and the specific plan of action (IWRP). This approach places a great deal of responsibility on individuals that ,in most cases, have had little or no formal training or experience in rehabilitation engineering or rehabilitation technology.

Organizational Structure for Training

The predominant organizational model of VR service delivery involves use of the local or district office. Small groups of vocational rehabilitation counselors, typically numbering 10-20 field staff, along with clerical and administrative support, serve their immediate geographic area. Regional offices and central administration provide overall management and direction. While the centralized activities of each VR agency are very important to the overall delivery and coordination of rehabilitation services, the function of the field offices remains a critical link in the delivery of services. This emphasizes the need to provide training on use of rehabilitation technology throughout the VR system. Concentration of training solely with administrative staff and centrally located rehabilitation technology specialists and rehabilitation engineers fails to adequately disperse information to the field office level.

While it is not the purpose of this paper to identify models of rehabilitation technology service delivery, this type of shared distribution and access to rehabilitation technology resources and expertise is suggested. There are a number of models of service delivery in use, each offering it's own advantages and limitations. Important with all of these, however, is the need to disseminate information and make available technical expertise to case load carrying counselors.

Strategy for Training

Training of personnel within the vocational rehabilitation system to effectively utilize and deliver rehabilitation technology services should be approached from a two fold perspective. Inherent in the effective use of any new resource or technique is the overall awareness and understanding of what that resource is. Presently the awareness of rehabilitation technology among overall VR field staff is limited. Therefore the initial phase or preliminary efforts of training should begin with developing a thorough understanding of the basic principles, scope and methods of what rehabilitation technology is all about. Without a functional understanding of rehabilitation technology, the use of these services will be limited and inconsistent.

The second facet of an overall training strategy should involve the development of specialized skills in the selection and application of rehabilitation technology services. These specialized skills should be developed within designated VR staff who would act as rehabilitation technology specialists in the local field offices. In addition, depending on the model being used for delivery of rehabilitation services, other centralized staff such as rehabilitation engineers or rehabilitation technology specialists with more in-depth knowledge and experience would receive advanced training. The training should also involve staff from various community based facilities and programs offering rehabilitation technology services. It is important that this be approached on a multi-disciplinary team basis whenever possible.

TRAINING APPROACHES

Although the need for training of vocational rehabilitation personnel in the use and application of rehabilitation technology has been clearly indicated, the methods and approach to providing this training is much less clear. The large number of VR counselors working in the various state agencies, combined with the number of staff from rehabilitation facilities and others involved in the use and application of rehabilitation technology, presents an extremely large, ever changing mix of professionals from varied backgrounds. A simple, single dimension training model will not meet the immediate need nor sustain long range quality assurance concerns.

Immediate Versus Long Range Needs: With the mandate for increased delivery of rehabilitation technology services, it is apparent that a long term training solution of pre-service, degree based education will not be able to meet immediate manpower needs. On an immediate need basis agency in-service and short term training sessions present a much more viable means of meeting current manpower needs.

An overall training strategy should however address both the immediate and long range scenarios. Unless plans are also implemented for preparing new service delivery personnel entering the field with skills in rehabilitation technology the full benefit of technology will not be realized.

Recommendations

The following training activities are presented as a recommended approach.

A Regional Training Model: The need to increase the systematic use of rehabilitation technology within the state/-federal rehabilitation program, the network of rehabilitation facilities and in the varied independent living centers has been well documented. The situation facing agencies and programs at this time is an immediate mandate to establish programming within very short time lines.

In view of these factors, a training program has been designed which specifically addresses the needs of professionals now working in the rehabilitation field by providing them with a combination of field based training workshops along with applied clinical, laboratory experiences which are designed to develop specific rehabilitation technology skills. This approach will assist in meeting the immediate needs for implementing rehabilitation technology services within agency and facility programming by providing an increased general awareness of rehabilitation technology resources for a large group of staff while also developing more concentrated skills in a select number of staff.

The training curriculum is organized in a series of sequential skill building units which culminates in completion of a core group of skills and competencies in rehabilitation technology service delivery. The training curriculum itself is organized into five basic phases. These phases are designed to be presented over a three year period within a regional area.

Clinical Affiliations: Common within many medically oriented disciplines such as occupational and physical therapy, prosthetics and orthotics and others is a clinical affiliation of "work experience" with established programs. This practice is much less prevalent within the vocational rehabilitation community. It does, however, present excellent options for the development of advanced, specialized skills for those staff who are being designated as rehabilitation technology specialists.

Regional and National Conference: Training associated with regional and national conferences can be a very effective way to meet some of the in-service needs of personnel. A varied array of topics are normally covered at these sessions. Limitations of these conferences to meet training needs stems primarily from geographic restrictions and their limited number.

Long Term Training: An important cornerstone of an overall training strategy to develop and maintain effective, high quality rehabilitation technology services is pre-service, bachelor and masters level education. This is being met to a limited degree by a handful of training programs that offer curriculum dealing specifically with rehabilitation technology. At the present time, however, there are only three to four programs identified which offer rehabilitation technology. These include New York University, Texas Women's University, the University of San Francisco, the University of Wisconsin-Stout and the University of Virginia at Charlottesville. The first two are based in occupational therapy programs while Stout and USF combine vocational rehabilitation and engineering/technology curriculum. The Virginia program focuses on rehabilitation engineering directly. There are other programs which offer limited coursework or units within courses which deal with rehabilitation technology.

An additional resource for long term training is the large number of traditional engineering and bioengineering programs. A concern with this, however, is the lack of exposure that these programs give to the rehabilitation process and individuals with disabilities in general.

SUMMARY

Meeting the training needs of service delivery personnel for rehabilitation technology is a complex and challenging task. Planning to meet these needs should include collaborative efforts between service delivery agencies, professional associations and consumer groups. The following are major issues that should be considered:

1. Funding for provision of a coordinated program of state and regional training activities to develop a general awareness of rehabilitation technology for existing rehabilitation, health and human service, education and private sector staff.
2. Financial support for the expansion of existing long term pre-service training programs and the development of additional programs to insure a supply of trained, well qualified personnel.
3. Funding for implementation of a regional network of advanced training activities designed to upgrade the skills and capabilities of rehabilitation technology service providers.
4. Initiation of a task force composed of representatives from professional associations, rehabilitation technology service providers, purchasing agencies, and consumers to outline the procedures needed to develop certification guidelines for the providers of rehabilitation technology services.
5. Grants for short term training for professionals already in the field to participate in training activities.

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TECHNOLOGY AND INFORMATION SERVICES IN GREAT BRITAIN

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This paper describes a few of the services and key players involved in information and technology service delivery in the United Kingdom. These are some of the services and information sources that I had access to, and used frequently, when I began working in London England, with young disabled people in pre-employment programs. The two main Parliamentary acts which govern services to disabled people are "The Chronically Sick and Disabled Persons Act of 1970" and its 1976 Amendment and The "Disabled Persons (Employment) Act of 1944. Responsibility for implementation of these two Acts are: The Department of Health and Social Security (DHSS), which is responsible at a central level for health, social services, social security, and rehabilitation; and the Department of Employment (DE), for employment, training and rehabilitation. The DHSS is a major purchaser of all rehabilitation equipment ranging from wheelchairs, prosthetics, and environmental controls, to incontinence garments.

Through a number of funded research centers the DHSS conducts the Aids Assessment program to assess the difficulties that disabled persons experience and identify the aids and adaptations which can be used to solve the problems. These programs evaluate design criteria, develop performance standards, and perform laboratory and field trials of all new aids under the DHSS charter. The results of the evaluations are publicly available and extremely valuable to both professionals and consumers to help in making informed choices.

Despite governmental attempts to regulate standards and introduce comparability between regions there are still wide variations in the services between local authorities. While certain duties are mandatory such as those concerned with the care of children, local authorities are allowed to define clients' eligibility for services, and to assess their needs. Inevitably, definition of need tends to depend on the availability of resources. Regional variation in the existence of services is further exacerbated by the variation in the maintenance of adequate staffing levels. There is an acknowledged shortage of skilled personnel. It has been estimated, for example, that within the field of occupational therapy alone there are over l,000 vacancies.

Quality of service, however, is not solely dependent on the quantity of resources and personnel available. More efficient use of existing personnel and services can improve both the quality and quantity of services. Working more at the community level, for example, means that avenues are gradually opened up for skill sharing and informed co-operation amongst all involved.

DISABLEMENT RESETTLEMENT OFFICERS. (DRO'S)

The Manpower Services Commission (MSC), a part of the Department of Employment, employs DRO's around the country working in Job Centers and employment offices to advise and assist disabled persons about ways to enter or retain employment and to advise employers on those jobs which could be done by disabled persons. Their main objective is to ensure that disabled persons can compete on equal terms with their fellow workers.

Some of the services offered include arranging occupational training courses, teaching resume writing and interviewing skills, arranging for the provision of special facilities and/or aids and devices, maintaining the Register of Disabled People and liaising with local employers to remind them of their obligations under the 1944 Disabled Persons (Employment) Act to employ a quota (at present 3% of the work-force) of registered disabled people and to identify those persons suited to sheltered employment.

The training for a DRO ranges from 14 1/2 weeks for those with previous employment service backgrounds to 35 weeks for new entrants. Although the DRO is taught many skills including interviewing, assessment, counseling, and knowledge of services available, little emphasis has been placed on providing technical information. In the past few years that has changed as more interest has been focused on computers and the employment opportunities that they have produced. The DRO's have to rely on the two technical programs run by MSC for support. These are the "Special Aids to Employment" program which involves the long-term loan of equipment and the "Adaptation to Premises and Equipment" program which involves capital grants to employers for modifying their worksites. These technical programs are usually staffed by experienced occupational therapists, engineers or persons with computer backgrounds.

In addition to the government programs, the Disabled Living Foundation (DLF), The Rehabilitation Engineering Movement Advisory Panels (REMAP), and Banstead Mobility Center are three charitable organizations that have attempted to expand their services around the country in the realization that retrieval of necessary information and technical expertise has to be community based, technologically competent and easily accessible for those living outside metropolitan areas.

THE DISABLED LIVING FOUNDATION

The Disabled Living Foundation (DLF), a charitable organization, is an information and demonstration center on equipment for disabled persons. It collects information on over 20,000 different aids, devices, programs and services. There are now 18 DLF aids centers around Great Britain and the DLF plays a leading role with the manufacturers of aids and devices, giving them design advice and informal evaluative information. Frequently, manufacturers will place their products in these centers for feedback.

Each aids center is composed of a large showroom, divided into functional living areas with products available for either demonstration purposes or as a pre-purchase testing site for consumers. The central Aids Center and Information Service in Harrow, London, which serves as the major link with the other aids centers is staffed by experienced Occupational Therapists and Physical Therapists. They work on a six week rotational basis between the Aids Center and the Information Service. This rotation is important as it gives the staff both the practical skills involved in demonstration and also enables them to keep up to date with the mass of new material. The DLF has found this to be a good recruiting tool as it offers a varied and interesting post.

DLF staff members also conduct research studies on specific areas of concern, such as wheelchair seating, transfer aids, adaptive driving controls, or music, sailing and gardening. Studies, typically of one year duration, gather vital information about their topic, which is incorporated into an annual report that is made available to the public through the aids center.One day intensive courses on a specific subject are open to the public for a fee every two months. These are always well attended by both therapists and consumers.

BANSTEAD PLACE MOBILITY CENTRE

Since May, 1982, Queen Elizabeth's Foundation for the Disabled has offered its facilities to any disabled person with outdoor mobility problems. The center provides driving ability assessments, car adaptation assessments, drivers' training and special programs for driving instructors. Major British car manufacturers provide demonstration vehicles with modifications fitted by car adaptation specialists. Other manufacturers have provided hoists and other transfer aids for drivers and passengers. Manufacturers of related equipment have provided such items as support cushions, "Help" pennants, other useful devices and publications.

Many manufacturers visit the center during the equipment design stage or with prototypes and this gives an opportunity for useful exchanges of ideas. Consumers, family members and therapists make the most frequent use of the center. One day courses designed for therapists provide a more in-depth knowledge of adaptive driving aids. Three day training programs for driving instructors are also offered. These include lectures on the disabilities most frequently encountered and their relevance to the need for vehicle modifications. The instructors are taught the practical aspects of these modifications and have ample time to experience using them.

Under the National Health Service a disabled person is entitled to a mobility allowance to help with transportation costs. This includes tax and licensing fees and parking permits. The mobility allowance is unusual in terms of benefits. It is an all or nothing award. That is, there is no criteria in terms of severity. If the doctor deems that a person has difficulty walking or can't walk, due to arthritis or quadriplegia, he or she gets the full mobility allowance.

In addition to the programs at Banstead,the Ford Motor company has financed a mobile mobility center. A therapist and driving consultant take a truck containing an adapted Ford Escort and a substantial range of mobility devices to 10 different destinations for up to a week each, carrying out an estimated 180 assessments a year.

REMAP

One of the most exciting and creative rehabilitation organizations in Great Britain is the Rehabilitation Engineering Movement Advisory Panel (REMAP). REMAP was born in 1964 through the need for a mobility device by a personnel manager at ICI, (Imperial Chemicals Industries, Ltd. one of England's largest companies). The manager asked the in-house engineers if they could help. The resulting success encouraged the engineers to look for other projects in which they could use their design and engineering expertise. In the ensuing years REMAP grew and various "panels" were set up around the country. It is felt that much of REMAP's success lies in the fact that as they grew they made the decision to join with the rehabilitation community as a whole. REMAP now operates under the auspices of RADAR (Royal Association for Disability and Rehabilitation) which is an umbrella organization containing almost all the 400 organizations within Great Britain that are concerned with disability. RADAR provides a central office and the primary funding for the five regional REMAP centers, each of which has about 20 panels. Most of the organizers in the regional centers are retired senior engineering managers from industry. They use their contacts with industry and academia for recruiting new volunteers, and locating materials and components for projects.

The local panels make every effort to recruit interested and informed occupational therapists who are considered to be key members. The occupational therapist who has a valuable background is the major source of case referral using his/her contacts within the local area health authority. The local panels, after receiving case referrals, consult, design and fabricate and then install the device. Because REMAP has a formal policy of not building aids that are commercially available, the therapist acts as the information broker and provides details of commercially available products to discourage re-invention.

The O.T. plays a pivotal role, in all aspects of education, training and service delivery. Although the aims of occupational therapists are basically the same (i.e. to enable the patient/client to achieve maximum independence in the physical, psychological, social and economic aspects of life), their methods of achieving this are necessarily very different inside and outside the hospital. For example, if an O.T. on a home visit sees a need for a product it is ordered immediately through the local authority and in most cases it is ready to go out to the patient on the next visit. In fact in many rural areas a domiciliary (home visiting) O.T. drives a station wagon carrying a wide variety of devices which are given out on the spot.

The domiciliary O.T. program is a recent innovation in England, that responds to that need, but it is struggling because of a chronic shortage of therapists. Two studies done in the 70's (2,3) found the need for PTs & OTs to have more community involvement, and that there was a need for more community and domiciliary experience during the training of therapists, and that these therapists should then be involved in the education and training of nurses, doctors, and social workers.

SUMMARY

Under the British system, The National Health Service is the provider of wheelchairs, nursing aids, aids to daily living, home adaptations, attendant care and mobility allowances. Materials necessary for custom designs, such as those made by REMAP, are reimbursable costs. These services and the integrated, closely knit service components make for more sharing. In many cases this is because of a tradition of local charitable initiatives, a country that is very small with fewer levels of government, in comparison with the USA, and a national profile that is not, on the whole, known for its entrepreneurial spirit.

Volunteers, whether they are retired physicians, engineers or carpenters, are eagerly welcomed on any issue in which they can offer a needed expertise. My own experience in learning about technology and then learning how to deliver it, was a 'make it up as you go along' program. I found that not only the organizations I have discussed in this paper, but many others were extremely helpful and open in sharing their knowledge and expertise. I'm sure that faults or holes can be found in this system, but within it, it is possible to become well versed in the art of appropriate technology and its place in the delivery of services to disabled persons.

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THE USE OF MICROCOMPUTERS IN THE REHABILITATION OF ORGANIC MEMORY DISORDERS

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Advances in the technology of microcomputers have contributed significantly to the rehabilitation of handicapped individuals, particularly those with sensory or motor handicaps. Progress in the field of cognitive and memory rehabilitation, however, has been somewhat less impressive. Although the microcomputer has appeared prominently in cognitive rehabilitation settings, its efficacy is still questionable.

Three reasons may be cited for the limited development in this area. First, rehabilitation workers, attracted by the time-saving features of the computer have tended to accept the microcomputer and the available software uncritically and to view it as a kind of cure-all. They have failed to recognize that the computer itself has no therapeutic value. Second, creation of software for "cognitive retraining" has frequently failed to take into account basic principles of cognitive psychology or to consider the special problems and needs of the cognitively-impaired users. Third, experimental psychologists have been slow to carry out research that delineates ways in which computer technology can best serve the needs of patients with neuropsychological disorders.

Many of the programs that clinicians embraced with such hope just a few years ago have begun to fall into disrepute because of their failure to produce positive outcomes. With respect to memory, it is now evident that most of these so-called "re-training" programs were based on the incorrect assumption that memory is like a muscle that can be strengthened or restored through practice. Virtually all of the memory re-training programs involve the repetitive presentation and study of items such as digits, words, or shapes--materials that have no real-world relevance. The misguided rationale underlying these programs is that drills or exercises will produce general improvements in memory function--a possibility that is not supported by scientific evidence.

A more realistic approach to memory remediation seems to be one that attempts to "alleviate" problems that are associated with memory disorders. Viewed within this framework, the microcomputer may well play a significant role. Two ways that a microcomputer may be used to facilitate patients' functioning in everyday life can be suggested: 1) A microcomputer may serve as an external aid, that is, as a sort of prosthetic memory, capable of providing information and prompts for everyday activities, and b) it may be used as a teaching device, to teach patients knowledge and skills that may be useful to them in their everyday lives.

EMPIRICAL WORK

Our research, over the past four years, has focussed primarily on the latter possibility: that patients may be able to acquire complex *domain-specific knowledge* that may impact significantly on their daily lives (1). Recent experimental findings have revealed that even the most severely amnesic patients retain the ability for some new learning. Our research has attempted to explore the limits of those learning abilities in the laboratory and to begin to delineate a range of real-world situations in which such knowledge can be applied.

The patients that comprise our experimental groups have memory deficits that have resulted from a variety of brain injuries or diseases including closed-head injury, ruptured aneurysm, temporal lobe abcess, and encephalitis. Their memory deficits are typically characterized by an inability to remember recent experiences or to learn new information. Accordingly, all patients have serious difficulty functioning in the real world. Although some of our patients also have other cognitive impairments, these are relatively minor in comparison to their memory problems.

Computer learning

Our initial series of studies focussed on whether amnesic patients can learn to operate, interact with, and program a microcomputer. We selected this domain of knowledge for both practical and theoretical reasons. The computer has the potential to serve as a powerful compensatory device if memory-impaired patients can learn how to operate it.

Earlier research suggested that patients with severe memory disorders could not learn how to use even a simple computing device. We wished to explore this possibility further. Additionally, computer knowledge represents a well-specified domain of inter-related facts and information that is well-suited to the experimental study of complex learning.

Our first study (2) investigated whether memory-impaired patients could learn a small vocabulary of computer-related terms. The teaching technique that we developed, the method of vanishing cues, was designed to tap patients' preserved abilities to produce previously studied material in response to fragment cues. Definitions (e.g., to store a program) were presented on a computer screen along with a fragment of the target word (e.g., S__). Fragments were gradually increased (e.g., S___, SA__, SAV_) until patients could generate the correct response (i.e., SAVE). On subsequent trials, letters were gradually withdrawn from the fragment until patients were able to produce the correct vocabulary word without any letter cues. If at any time patients were unable to produce the target, letters were added back. Using this procedure, four patients learned approximately 15 new items of computer vocabulary.

Later studies (3,4), using the same vanishing cues procedure, demonstrated that patients with memory disorders of varying severity can also learn to perform simple operations on a microcomputer. Although rate of learning was slow and far from normal, patients successfully learned to display and clear messages from the screen, store and retrieve information from a disk, and write and edit simple computer programs. Even the most severely-impaired patients, despite being unable to remember ever using a computer, nevertheless demonstrated that they had acquired the new computer knowledge and skills. Moreover, there was little loss of this learning over intervals of 7-9 months.

Although these findings provided some reasons for optimism concerning the eventual use of computers by memory-impaired patients, they also revealed some problems. The knowledge that was acquired by patients appeared to be quite inflexible or hyperspecific. That is, it could only be retrieved under a narrow range of circumstances, specifically those that had been present during training. When stimulus conditions were changed, patients were often unable to recall the appropriate responses. This observation suggested that knowledge and skills acquired in the laboratory might not readily transfer to real-world domains. Our next series of studies addressed this issue with respect to one important domain of everyday life--the workplace.

Vocational training

We attempted to determine whether knowledge and skills acquired in the laboratory could be applied in a real-world job. Based on our experience in the computer-training studies, we specified a number of job characteristics that we thought would be important to the successful outcomes of vocational training programs. First, suitable jobs are likely to be those that require a set of relatively invariant procedures. Patients are unlikely to be able to perform tasks that require problem-solving, hypothesis-testing, or flexible use of acquired knowledge. Second, complex jobs must be broken down into component steps with each step being taught explicitly and directly. Third, laboratory training should mimic the job situation as closely as possible in order to minimize transfer problems. Because of the hyperspecific quality of the knowledge that patients acquire, they have difficulty handling novel situations and are unlikely to make inferences on their own. Tasks should therefore be taught under conditions that are as similar as possible to those that exist in the actual job situation.

Our first vocational training study (5) involved a 32-year old woman who had become severely amnesic following encephalitis. Working with her employer, we identified a job that seemed suited to her capabilities and had the characteristics noted above. The job was a computer data-entry job that required the patient to extract multiple pieces of information from company documents and enter them into a computer display that consisted of nine coded columns. Although the job was complex and required the learning of substantial amounts of information, the task once acquired was invariant over time. The method of vanishing cues was used to teach all informational or knowledge components of the job in the laboratory. Extensive practice was then provided to allow the patient to develop speed and efficiency in the actual data-entry procedure. Although the patient initially performed extremely poorly, she gradually learned the task in the laboratory over a period of several months after which time she was able to carry out the procedures rapidly and without error. More importantly, after a short period of supervision and practice in the workplace, the patient performed on-the-job as efficiently as experienced company employees. Interestingly, although able to perform at this high level, the patient was still unable to recount specific details of the procedure.

Our characterization of suitable jobs suggests that jobs requiring data entry and perhaps other computer-type tasks are excellent candidates for job training: Once mastered, learned procedures can be executed repeatedly with few demands made on memory or high level cognitive processes. Computer-related work also has a "high-tech" image that makes it particularly appealing to memory-impaired patients whose self-esteem may be low. Our procedures, however, need not be confined to computer jobs. They can be easily applied to many other tasks. For example, we have used the microcomputer with the method of vanishing cues to teach a patient various aspects of a microfilming job (6).

Our most recent research has explored vocational tasks that are much more complex than any used previously. As yet, we have observed no limit on the amount or complexity of knowledge that can be acquired by memory-impaired patients. It is certainly conceivable that although the learning process is slow, a great deal of information can be learned and retained by memory-impaired patients that could significantly improve their ability to function in broad areas of everyday life.

CONCLUDING COMMENTS

Our research to date demonstrates that patients with serious memory disorders can learn complex knowledge and skills within a specific domain that can impact importantly on their daily lives. We have investigated only a few domains; many others remain to be explored--vocational, educational, domestic, social and so on. In addition, we have studied only a few patients. The method of vanishing cues has proven to be an extremely effective technique for teaching new information to patients with memory impairments. Other intellectually or cognitively impaired populations may benefit similarly.

The microcomputer has played a significant role in the development and implementation of our research. The method of vanishing cues relies heavily on the computer to keep track of the patients' progress and to provide cue information as required. Our training programs are all interactive: Stimulus conditions on each learning trial are dependent on the patients' performance on prior trials. In addition, patients can work at the training programs independently and at their own pace; the experimenter or therapist does not need to be present. These features make the computer a valuable tool--but not a magical cure. Continued research is needed to ensure that guidelines are developed to specify the ways in which computers can and cannot be used productively to benefit disabled populations.

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PROSPECTS FOR APHASIA REHABILITATION

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Patients with severe aphasia face an enormous obstacle in dealing with the ordinary tasks of daily living, i.e., their inability to communicate reliably their needs, thoughts and feelings and in many cases, to understand such communications from others. Unfortunately, approximately one fourth of patients afflicted with aphasia are left with severe deficits (8) and it is precisely this segment of the aphasic population that is most difficult to aid with conventional speech therapies. Non-linguistic communication systems, e.g., VAT (7) and drawing (11) have proven useful for some patients, but fall far short of providing the communicative power of natural language. Patients using such systems remain severely limited in their range of expression. Most existing alternative communication devices are designed for patients with impaired *speech*, and do not address the problems of severely impaired aphasic patients whose deficit is impaired *language*. An ideal orthosis for severely aphasic patients would provide an inteface between their thoughts and feelings and the natural language employed by the neurologically intact population. In this presentation, we will explore progress towards -- and the prospects of achieving -- this goal.

It may be useful to define the characteristics of an ideal interface for severely aphasic patients and to review the conceptual and practical shortcomings of existing approaches. First, a useful language interface for severely aphasic patients must compensate for the motor handicaps, hemiparesis and apraxia suffered by most of these patients. The original VIC (VIsual Communication) system, described by Baker, et. al. in 1975 (1), was shown to be a potentially effective communication system for severe aphasics, but was never successfully transferred outside of the laboratory: his system was implemented on index cards, and the manipulation and organization of stacks of cards proved too great an obstacle for hemiparetic patients. Primarily for cognitive reasons, interfaces designed around a keyboard, such as the "intelligent word finder" (4) have proven too difficult to use except by the mildest aphasics. Contemporary microcomputer technology affords new approaches which are accessible to severely aphasic patients and transparent to normal users. The "mouse" -- a handheld, two dimensional tracking device including a finger operated switch -- is the most widely distributed device appropriate for use by aphasic patients. The C-VIC 1.0 (Computerized VIsual Communication) interface for severely aphasic patients is entirely controlled by mouse input (14). Aphasic patients readily learn the use of this system and achieve much faster access times using the mouse than when manipulating cards (13). Joysticks, trackballs and touchscreens may also be appropriate input devices for use by aphasic patients.

The ideal communication interface for severely aphasic patients must compensate for much more than a motor deficit: it must compensate for severe linguistic and certain cognitive deficits as well. A partial list of some of the possible deficits suffered by severely aphasic patients includes: decreased working memory capacity, neglect of part of the visual field, difficulty in utilizing principles of semantic organization resulting in disproportionate difficulty with vocabulary in certain syntactic categories, decreased ability to utilize syntactic rules. Sign language might seem to be an appropriate medium for aphasic patients to communicate in, however, the generally disappointing performance of most aphasic patients in learning to sign is attributable, at least in part, to some of the problems enumerated above. Apraxias and visual neglect can certainly lead to impaired expression and reception, respectively, of manual signs. In a recent study, Coelho and Duffy (3) noted that the inability of patients to acquire manual signs appears to correlate positively with the severity of their aphasia, and the most severe aphasics were able to learn no more than a handful of signs. In contrast, severely aphasic patients have learned over two hundred symbols in the C-VIC system. These symbols are stored by the computer and are recognized and retrieved, but do not have to be recreated anew each time by patients.

The semantic fields of aphasic patients appear to be largely intact, although patients may not be able to access the information in the fields in normal discourse. For example, while retaining certain information about superordinate categories, aphasic patients may be unable to spontaneously produce appropriate words or symbols. In C-VIC 1.0, an implicit hierarchical organization of common nouns was introduced. Common nouns were divided into four categories: food and objects relating to food, clothes and body parts, buildings and large appliances, and sundries. This organization allowed for reliabale access of a large number of common nouns in the system, and even the most severely afflicted aphasic patients demonstrated an impressive facility in mastering this access scheme and using it to retrieve noun icons. In our current work, we are expanding and extending the potential foruse of hierarchical organization as a retrieval and cueing strategy.

Caramazza and Zurif (2) established that patients with agrammatic Broca's aphasia have difficulty using syntactic rules to decipher the meaning of statements. Some invesitgators have argued that syntactic processing capabilities specifically reside in the anterior language area of the frontal lobe. We have demonstrated that severely global aphasic patients with extensive destruction of anterior as well as posterior language areas can master a simple visually-based syntax. For instance, in one study designed to replicate results obtained in previous studies of agrammatic patients (15), we have shown that a severely global aphasic patient can make use of a simple visually-based syntactic rule for visual symbols regarding the use of prepositions. While the extent to which severely aphasic patients can use syntactic rules for visual symbols is unknown, it is likely to be more restricted than the capacity of intact humans to use syntactic rules in decoding linguistic input.

In this regard it is interesting to note the particular difficulty aphasic patients have in using verbs, both in the original VIC studies (5) and in C-VIC. Luria (10) noted that his patients with expressive aphasias had great difficulty retrieving verbs and for these patients, he emphasized re-education in forming simple sentences with verbs. Receptive aphasics are likely to have grave difficulties in using verbs as their associations between objects and verbs appear to be the most damaged feature of their semantic organization (6). More recently, the central role of verbs in retraining aphasic patients has been formally addressed (12). In the original VIC study, and in our own work with C-VIC, patients make more errors in using verbs than other syntactic categories, require more training to learn to use verb symbols correctly, and appear more unsure of their use. While the representation of verb symbols as abstract or concrete symbols may influence the ease of acquiring a new symbol, patients appear to have equally great difficulty in generalizing either type of static symbol to new situations (16). We are currently working to implement several new features in C-VIC which may aid patients' performance in using verb symbols. Animation will be provided to augment patients'comprehension of static symbols. Contextual cues will be provided with representations of whole scenes of activity. Finally, the interface will be able to provide the most likely verbs and prevent patients from choosing impossible verbs to use in conjunction with objects or phrases already selected by them.

The ideal interface will also provide capabilities for encoding sets of instructions and help routines to aid in the performance of more complex tasks of daily living. This approach had been useful in training both memory impaired (9) as well as aphasic patients on cooking tasks. Thus, we have shown that a severly global aphasic patient can consistently perform at a much higher level in following recipes written in C-VIC than in following identical recipes in spoken or written English.

An important design feature, largely lacking in the current C-VIC interface, is the ability to tailor the properties of the interface to the capacities and needs of the patient. In the current version of C-VIC, only the vocabulary "deck" can be modified. Future versions of C-VIC will provide the ability to control nearly every aspect of program operation. C-VIC "cards" may be operated upon by a number of different "tools", for example, the operator to search up and down a hierarchy, or the operator to animate or to pull up associated symbols. The depth of hierarchical organization and the tools accessible to the patient will under program control and modifiable.

We have explored some of the desired capabilities of an interface for severely aphasic patients and some design concepts we are now working to implement. With this additional power available, we will be able to begin exploring not only further rehabilitation of severe chronic aphasic patients but also the introduction of multi-modal, computer-aided therapy in recovery from acute aphasias.

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IMPROVING FUNCTIONAL PERFORMANCE WITH COMPUTERIZED TASK GUIDANCE SYSTEMS

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INTRODUCTION

Many neurological disorders are often associated with newly acquired cognitive impairments. These changes can be quite devastating for individuals who experience severe disruption of their personal and vocational lives.

As previously noted (2,4), many techniques have been advocated for remediating cognitive deficits. These techniques vary in the degree to which they:

A. attempt to "restore" compromised cognitive processes in contrast to developing compensatory strategies;
B. stress the retraining of component neurocognitive abilities in contrast to the performance of higher level functional tasks; and
C. emphasize alterations in the patient's environment in contrast to modification of the patient's own skills and abilities.

In our work, we have focused on environmentally based, compensatory interventions for functional activities. We call this type of intervention a cognition orthosis. Cognition orthoses are a familiar part of daily life. For example, a knot tied around an index finger, or notes on the refrigerator can each facilitate everyday functioning for tasks which rely primarily on memory skills. Similarly, the use of a cookbook facilitates the completion of a complex sequential activity by providing step-by-step instructions.

Earlier reports have also advocated the use of compensatory, environmental cuing devices. For example, Harris (1) has discussed the use of "external memory devices" such as clocks and calendars to facilitate recall. Unfortunately, many patients are unable to benefit from such assistive devices because their use requires initiation, planning and memory skills.

More recently, Schacter and Glisky (5) have proposed techniques such as "faded cuing" (i.e., compensatory, functional, person oriented interventions) which are designed to promote learning of "domain specific knowledge". Detailed information is provided during early learning trials, but is systematically withdrawn as the individual learns. Using this technique, Schacter and Glisky (5) have been able to enhance the performance of amnesics on isolated (but functional) tasks.

In our work, we have specifically investigated a particular type of cognition orthosis which we call a computerized task guidance (CTG) system. A specialized microcomputer language called COGORTH (from COGnition ORTHosis) has been developed by our research team (3). This language permits the relatively easy design of CTG systems which:

A. provide cuing at any level of detail required by the user;
B. are dynamic and interactive
C. provide multi-modal cuing
D. control and manipulate electrical devices in the environment; and
F. work in "real-time"

Using these features, CTG systems can compliment and extend the acquisition of domain specific knowledge by enhancing compensatory performance across task domains, times, functional settings, and interpersonal contexts.

REPRESENTATIVE USES FOR CTG

In this section, data from two subjects will be described. These subjects respectively participated in one of two ongoing studies investigating the use of CTG.

A. Study I.

A 39 year old male received a severe traumatic brain injury approximately ten years prior to his participation in the study. Very limited medical records indicate that he remained in coma for 15 days. At the time of the study, the patient, who lived in a residential group home, required on-going cuing and supervision and frequent review of critical information for many aspects of daily self-care daily. He had been participating in a sheltered work evaluation program, but his behavior was often marked by unpredictable emotional outbursts (partially controlled with a simple reinforcement program).

Complete neuropsychological data were not available. Findings from an abbreviated evaluation provided by the treatment facility indicate adequate attention and concentration but moderate to severe deficits for both the immediate and delayed recall of verbal and pictorial information. Perceptual reasoning skills were moderately to severely impaired. Achievement testing indicated that the subject was functioning at the fifth grade level for reading.

Method

The larger study in which this patient is a subject employs an ABABA single case design. Subjects are asked to perform a 90 minute sequence of 23 representative janitorial tasks. The conditions for the single case design are: A trials - perform tasks with detailed written directions; B trials - perform task with a CTG system. The subject's performance for each task is scored by two independent trained raters.

Results

Data are presented in Figure 1. (N.B. Y-Axis is sub-tasks correct). As can be noted, the patient experiences relative difficulty completing many components of the janitor's job when using detailed written directions. However, consistent improvement can be noted when CTG is used. When CTG is withdrawn the subject consistently returns to his baseline performance.

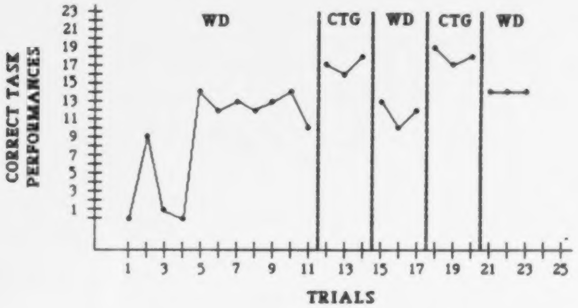

FIGURE I. NUMBER OF CORRECT SUBTASK PERFORMANCES ON A JANITORIAL TASK BY A 39 YEAR OLD MALE USING VRITTEN DIRECTIONS (VS) AND COMPUTERIZED TASK GUIDANCE

Discussion

The study suggests that computerized task guidance promotes improved performance. However, further work will be required to determine the characteristics of patients who require CTG as opposed to those who can transfer learning to a technologically less intensive intervention technique. The subject presented in the second study addresses this issue.

B. Study II

A 48 year old male sustained multiple injuries when a large piece of machinery fell on his chest at work. He was recovering well until 11 days post trauma, when he experienced a cardiac arrest. During this time the patient was anoxic for an undetermined period of time. After emergency intervention the patient subsequently made a good physical recovery. However, severe cognitive changes associated with his anoxic episode were evident. These changes, supported by neuropsychological evaluation, included: mild to moderate intellectual decline; severe verbal and perceptual memory deficits; and difficulty with tasks requiring strategy formation and set-shifting. Two separate studies will be reported for this patient, each addressing a different functional area.

1. CTG for control of incontinence

The patient's Foley catheter was not removed until 40 days post trauma. At that time he was confined to bed because of severe pelvic fractures. It was therefore necessary for him to use the urinal but, instead, he would repeatedly urinate in bed without it. Clinical observation suggested that cognitive deficits were interfering with his ability to initiate the use of the urinal.

Method

Using COGORTH, a CTG system was developed. A portable computer was placed at bedside. Every two hours the system provided auditory (i.e., rapid beeping) and written cues instructing the patient to use the urinal. He was requested to press a single key on the computer keyboard to indicate when he had finished urinating at which point a cue was presented instructing him to return the urinal to his bed rail. The computer would then remain silent until two hours had passed at which time the cuing sequence would repeat. This method was used with the patient for four hours a day on each of three days. At the end of three days the computer was removed to observe the patient's spontaneous bathroom activity.

Results

During the three day trial the patient responded to all computer cues and experienced no episodes of incontinence while computer cuing was provided. One episode of incontinence occurred on the first day of trials while the computer was not in operation. However, no episodes of incontinence occurred
during the second two days of trials with or without computer assistance. The computer was discontinued on day four. However, the patient remained continent from that time on.

Discussion

It does not appear that the patient learned to use his urinal in response to CTG. Instead, it is likely that the computer had been introduced during a period of spontaneous recovery after which the patient was able to assume cognitive responsibility for spontaneous urination.

2. CTG for a complex cooking task.

By the tenth week of hospitalization the patient was still severely amnesic. Although he was now washing and dressing himself independently, problems with initiation, problem solving, planning and organization persisted. As part of the patient's regular Occupational Therapy program, he was attempting simple cooking tasks. However, he would frequently become confused when attempting these tasks and required ongoing intervention from the therapist.

Method

A study was designed to assess the patient's ability to benefit from CTG in contrast to specially adapted written directions. The study was originally conceived as a ABA design but modifications to that design were made as the study progressed. These changes and their rationale will be discussed below.

Two types of cuing systems were developed for a complex cooking task (i.e., baking applesauce muffins). A specially adapted set of written directions was designed consisting of 8" x 10" index cards, arranged as a deck on an upright three ring binder. Each index card presented a single instruction for the cooking activity. Additionally, each card instructed the patient to turn the card over when he had completed that task. A CTG system for applesauce muffins was also developed. Using COGORTH the computer was programmed to keep track of cooking time and to interrupt the patient with appropriate instructions when the applesauce muffins were to be removed from the oven. In contrast, the index cards instructed the patient to set a minute timer. For the purposes of scoring, the cooking task was divided into 17 functional sub-units. Two trained raters observed and scored the patient's performance for all trials.

Results

Data are presented in Figure II. (N.B. Y-Axis is subtasks incorrect). During baseline trials with index cards (IC) the patient made many errors ranging in severity from mismeasurements to forgetting to remove the muffins from the oven. During the second series of trials (CTG) performance improved considerably over a single trial, suggesting that improvement could not simply be attributed to practice.

Consistent with the original ABA design, the patient was then asked to perform another series of trials using IC cuing. As can be seen in Figure II, the patient's performance on the task remained at the same level as with CTG. Two possibilities were entertained. First, that the patient had learned the cooking task itself. Second, that computerized cuing facilitated the use of the IC system. The patient was therefore asked to perform a single trial of cooking with no cuing other than the standard recipe. As shown in Figure II, the patient's performance returned to its original baseline level. The patient was then asked to perform a final series of trials using index card cuing and was able once again to successfully perform the cooking task.

Discussion

In this study, the patient appears to have benefited in two ways. First, the quality of his performance on a complex functional task improves substantially when computerized cuing is introduced. Second, the quality of his performance subsequently appears to improve while using non-computerized cuing as a result of practice with the CTG system.
It is possible that the patient's performance with index cards would have improved anyway if he had been given additional practice with the non-computer technique. Alternatively, the results of this study suggest that it may be possible to teach cognitively impaired individuals a method for effectively interacting with a cuing system - a skill that can then be generalized across tasks.

OVERALL DISCUSSION

Two examples have been presented of patients who benefited from computerized task guidance systems. However, like any intervention, this approach has its limitations. Some individuals may find computer interaction objectionable. Other subjects may be too severely impaired to effectively interact with a CTG system. Attentional problems or decreased motivation may also prevent a patient from reliably responding to computer cues.

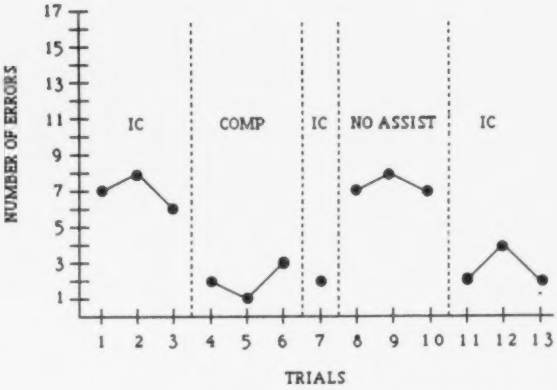

FIGURE II. NUMBER OF ERRORS PER TRIAL FOR A 48 YEAR OLD MALE PERFORMING A COMPLEX COOKING TASK.

IC = INDEX CARD CUING
COMP = COMPUTERIZED TASK GUIDANCE
NO ASSIST = STANDARD RECIPE

Despite such potential limitations, one advantage of CTG systems is that they can be easily modified to meet special needs. This feature permits clinicians to use an empirically based, functional approach during treatment, modifying a program in any way necessary to improve patient performance. Further work is clearly required to define the clinical parameters which influence the effectiveness of CTG systems as well as the types of tasks to which they may best be applied.

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TECHNOLOGY TO ASSIST PHYSICAL FUNCTION AND AID INDEPENDENT LIVING
(SPECIAL SESSION OVERVIEW)

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This session focuses on "technology for independent living" which we define as that pervasive supporting technology which is needed to underpin the routine activities of daily life. Our intention in this session is to describe the range of ways disabled people get the equipment and related services they need. Technology for independent living is sometimes specialized compensatory technology, though often it can be regular technology carefully selected for functional ability or used in a nontraditional way. The emphasis here will be on the things one would normally use at home, keeping in mind of course that the majority of the things one does at home, like eating, walking, getting up from a chair, washing one's hands, putting on a jacket, etc., and generally also need to be done anywhere else one goes too. Technology considered here covers basic bodily functions, including equipment that is medical/health/therapy related; mobility equipment; and products that enables function broadly, e.g., reaching to pick up an item from the floor, or an attachment that helps one open a door. Generally it belongs here if one needs it to make one's other applications technology work; e.g., if you cannot go to the toilet independently, you are going to need to resolve that concern if you are going to work in an office, or attend classes. We are not focusing on devices that are application specific (e.g., those related to education, employment, and recreation) since those are generally covered by one specifically designated system.

This category is often what is left over when all the "interesting" technology is separated out for investigation. This area is usually taken for granted, and in fact overlooked, even by disabled advocates. It is usually more mundane than glamorous, rarely involves high tech or computer applications, and if it is working right, and working as a system, it can and should fade into the background.

This type of technological support is all pervasive. It is also intrinsically related to adaptive strategies, personal care attendant services, and environmental modifications. Without some combination of these supportive services, one may be unable to get into one's house, out of one's bed, or to get oneself a drink, take a bath or get one's clothes on. Which combination of supportive services are used is very individualized and changes over time and circumstance. When everyday technology is discussed, it is assumed that its interrelationship with these other supportive services will be kept in mind.

We are placing technology in the context of real life situations for the majority of disabled persons. We will describe how a consumer gets and uses technology when he or she is not a part of any formal intervention system, since realistically at any given point in time, we know that most disabled people are not "enrolled" in the formal habilitation/rehabilitation systems.

It is sad but true that, all too often, daily living problems are "solved" by doing without technological support, and just accepting the enormous hassles in one's routines as part and parcel of living with a disability. When devices are obtained, they are often purchased out of pocket, sight unseen, with no reliable evaluative or comparative data available to make an informed decision. They are often more expensive than related products in mass markets. Common sense and practical experience tells us that these devices are not medical appliances, yet in many reimbursement schemes, we are forced to describe them as medical necessities if third party funding is to be secured. This myth of medical necessity inhibits understanding or incentive to design so called "therapy" equipment to be narrow, lightweight, aesthetic, or comfortable, or to support the regular routines of everyday life in a practical or functional mode. Then we wonder why this equipment does not work well for disabled people living at home! The wonder is that more disabled people are not complaining about it. Actually, if you are out in the disability community, they are complaining about it, but since most professionals have little exposure to disabled people who are not in some rehabilitation system or having serious problems requiring professional intervention, we often forget that they exist.

ADVANCES IN TECHNOLOGY: A MASS MARKET ARENA

There have been many new and interesting special products developed or adapted in the past few years. However, most of the significant advances in daily living aids for disabled people have been mass market products and services designed for lazy yuppies. BSR environmental control units from Sears, automatic garage door openers, microwave ovens, speaker phones, bidet-type toilet seats, waterbeds, personal computers, edible TV dinners and other convenience foods, food processors, oven rack pullers, automatic dishwashers, home security systems, Niagara beds, velcro shoe closures, jogging suits as acceptable streetwear, vibrators, hot tubs, hand held shower massage units, electric toothbrushes, electric can openers, remote controls for almost everything, and on and on. I believe this trend will and should continue, and that the best way to develop accessible commercial products may actually be by increasing the "disability awareness" of mass market product design professionals.

FOCUS ON TECHNOLOGY DELIVERY SYSTEMS

We are focusing this session on delivery systems rather than on specific devices, because the real issues in this area reach far beyond innovative new products. The way people obtain these most basic supportive technologies is profoundly effected by public policy. In the U. S. Congress Office of Technology Assessment's 1982 report Technology and Handicapped People, the major conclusion reached was that "despite the existence of numerous important problems related to developing technologies, the more serious questions are social ones--of financing, of conflicting and ill-defined goals, of hesitancy over the demands of distributive justice, and of isolated and uncoordinated programs." This statement is just as valid in 1988 as it was six years ago. It is probably more true for technology for independent living than for any other kind of supportive technology.

In order to discuss the delivery system broadly, we have arbitrarily divided it into three parts based on the age/stage in life of the technology user: children (0-21), adults (22-64), and seniors (65+). A paper describing technology delivery systems for each age groups follows.

There are several different frameworks that could be used to describe the current state of the art in delivery systems for technology for individuals with disabilities. These include categorizations such as: level of need/level of support; society's perception of need: the health/medical/sickness orientation vs. the public health/nonmedical/wellness model. However, the most realistic way to describe how disabled people get their equipment is to admit there really is no coordinated system, and that third party reimbursement systems drive the both the distribution and the development processes. Since public policy related to reimbursement is most often categorically tied to age, we used years rather than types of equipment, geography, or the enormous range of available programs, to classify the delivery systems. It also seemed a more holistic, person oriented approach.

INTENSITY: LEVELS OF INTERVENTION

While age/stage in life may provide a useful grouping for discussing the service delivery systems, it is also helpful to remember that disabled consumers could also be categorized according to the intensity, i.e., level of intervention required in obtaining and successfully using assistive technology. Within any given age range, the following types of service delivery intensities must be considered:

Level I: Most people seeking technical aids fall into this category. They basically need information about what is available, and where to get both the information and the device. They tend not to be connected into the rehabilitation system, nor have that any ongoing need to be. If there were a "Consumer Reports" type publication which could lay out the device features, comment on each, and let the consumers decide the trade-offs, it would more effectively meet this group's needs. Because this is a large and growing group, mass market media channels could be used to help steer them to existing specialized information systems, while reminding them to seek help from local public libraries, and to look for local chapters, organizations, and societies such as the Arthritis Foundation, the Easter Seal Society, or the United Cerebral Palsy Association in the yellow pages of the phone book. Because rehabilitation professionals rarely interact with this group, we tend to forget they exist. Their equipment needs are often simple and straightforward, which must make their search through our "turf" all the more frustrating. This group includes the elderly who need to compensate for gradually decreasing physical capacity. Because this group is so easy to overlook, it is especially important to remember to include their type of needs in research and development, program planning, outreach, and information dissemination efforts.

Level II: This group generally uses standard rehabilitation-related products, they may use the rehabilitation system from time to time, and they generally have an idea of where to go to get the equipment they need. They may be receiving occasional services from an Independent Living Center or other established program, and they know how to use the equipment experience of other consumers to help get their needs met. They would look to the professional for help in the selection process, to expedite delivery time, and perhaps for training in use of the device. A competent DME/HME (durable medical equipment/home medical equipment) dealership can often provide this level of service on its own or in conjunction with referrals to and from a local therapy department.

Level III: The third category involves the fewest number of customers, but the greatest amount of intervention. These clients tend to be more severely disabled, have more complicated equipment needs, have a larger number of service systems and professionals involved, and generally require a total team approach, thorough evaluation, customized fabricated equipment, training in use of the devices, a shakedown trial use period, and follow-up. These cases can be expensive, time-consuming, and challenging, and require considerable ongoing coordination. These clients tend to be "known" to the system professionals, especially when there is a source of funding to support needed services.

SHOULD INTERVENTION LEVELS CORRELATE TO AGE?

It is interesting to note that even though there are disabled people of all ages in each of these categories, service delivery systems seem to target one age group per category. The Level I stereotype is evident in the emerging market for simple daily living devices for older people, mail order catalogs seem especially popular. Level II tends stereotypically toward the active young male paraplegic, though the emphasis is on adults in general. Services in Level III seem most organized for children, especially in programs where seating and communication aids are common fare.

When asked to prepare papers for this session, the individual authors were asked to include in their descriptions how the system worked from the perspective of all three levels of intervention. None of us were able to readily do that. I suspect it is because systems are not developing within any age group that would provide a continuum of service intensities to match the continuum of needs. This matter deserves further analysis. It may be one reason why there are so many unmet needs, despite the fact that there are a considerable nnumber of programs related to technology provision. It could also be one of the prime reasons there is such difficulty transitioning between systems -- we may all be talking about disabled people, but we are not discussing the same types of disabled people, or the same types of intervention needs. Is there any question that frustration would exist when professionals from, for example, special education, vocational rehabilitation, and the field of aging try to agree on a common agenda related to assistive technology for individuals with functional limitations, if the problem stated above accurately reflects the current state of the art? It may be time to acknowledge that we are all seeing the proverbial "elephant" from totally different perspectives, to take off our "blindfolds" and see what we have our hands on. It is also time to include the "elephant" in the dialogue.

RESOURCE ALLOCATION ISSUES

Technology must be viewed in context. Resource allocation decisions are influencing the individual's ability to select the best combination of options for community-based living. A piece of hardware is not the only way to solve a problem. It is one option. Others include: personal help, learning new skills, adapting the environments, an redefining the problem. It would be unlikely that anyone but a "techie" would approach an everyday living problem by asking "What gadget can I get to solve my problem?" Most of us look at the range of possible options, determine the tradeoffs, the resources available, and then make a decision. However, where technology is concerned, we already are learning to write reimbursement documentation for technology in terms of cost reduction/effectiveness (e.g., if this widget is provided, it will reduce the need for attendant care services). It will indeed be unfortunate if supportive services which should be considered in combination (personal aid + technical aid + environmental adaptation + training = community-based support system) are seen as discrete alternatives to each other (personal aid or technical aid or environmental adaptation or training = ????). These issues can be seen most clearly around technology because it is so tangible, but it is clear that similar issues exist in all the supportive services connected to what the medical model might call "chronic care needs." We do not suggest simply providing more of anything; but to carefully look at how and what is being provided, and why it is being provided (or not being provided).

It is critical that players in all areas of this complex puzzle begin working together to avoid fragmentation and the inevitable turf battles that will result if these services are pitted against each other. Denial of services is clearly one way to reduce costs. If advocates are not there, unified, to watchdog and produce verifiable information to policymakers about the ramifications of their decisions, we may find the types and combinations of services and products we need effectively excluded from reimbursement.

Whether we approve or not, policy and resource allocation for rehabilitation services and assistive technology for older, functionally limited Americans and for younger disabled Americans is clearly connected, and whichever group precipitates a change, both groups will benefit (or suffer). We no longer have the luxury of pretending that these systems do not at least indirectly influence each other. Other countries have dealt with these issues in a more comprehensive and comprehensible manner. It is time for us to gain a better understanding of real needs, and to devise systems that will provide appropriate community-based support for disabled people of all ages, and with a wide spectrum of needs.

The independent living movement, a growing elderly population, technological opportunities, and younger generations who expect technological solutions to be readily available are coming together to generate a fertile field for advancing the current state of the art in applied technology. We must plan for delivery systems that will match need and expectation.

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Assistive Technology for Older Adults: Funding Resources and Delivery Systems

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Assistive technology for daily living has been available for years. However, it is only recently that it has been actively considered for older users. Technology applications for the elderly is now a burgeoning topic in the gerontological and rehabilitation fields as evidenced by the number of special focus sessions and entire conferences designed to highlight technology and aging issues. Despite the amount of attention given to these issues by professionals from various fields, there is still a great lack of both knowledge about and use of assistive technologies on the part of most older adults. This paper focuses on some of the reasons why technology use by persons age 65 and over is still primarily in the minds and dreams of professionals rather than in the hands of those in need.

Who Are the Potential Users of Technology in the 65+ Age Group?

There is no other age group that can be characterized better by heterogeneity than the elderly. There is no one "type" of older person, especially regarding capability. Everyone has heard about the very capable person in her late 80's or 90's. Equally common is the very frail or disabled person in her 50's or 60's. Significant numbers of older people fill every cell in the matrix of age by capability. This makes the application of technology for older adults a complex and often confusing problem.

The heterogeneity of capability in the older population is reflected in the service delivery intensities or levels of intervention appropriate for this group. Level I, the least intensive intervention would best characterize the majority of well elderly. Due to age related decreases in many basic areas of functional ability, this group of older adults would greatly benefit from the use of assistive technology. A few brief examples from basic research on activity of daily living (ADL) task performance by older adults can be used to highlight appropriate areas of technological application. A series of research projects were conducted at the Stein Gerontological Institute to investigate ADL performance by healthy older adults living independently in the community (Faletti, 1984; Faletti & Clark, 1984; Czaja, Clark, Weber & Faletti, 1988). Data from this research have indicated that this group of individuals experiences a significant number of problems in the accomplishment of daily tasks. For example a large percentage of our sample has reported regular problems with ingress and egress tasks, the most predominant of these difficulties being getting in and out of the bathtub. Another frequent problem reported was in the task of meal preparation. Opening jars appears to present a problem for a great many older persons. A closer look at biomechanic measures of grip strength in this healthy older sample reveals that indeed, grip strength is significantly reduced in this population, most often below that which is required to complete routine ADL tasks like opening jars. The striking feature of these data is that they reflect problems experienced by well, capable elderly receiving no assistance with their daily tasks. The healthy older person, then, could greatly benefit from the use of assistive technology interventions.

Although this level of

assistance can be considered as intervention, it may be helpful to view them also as preventive assistance. As an example, consider the normal age-related declines in balance recovery. The use of devices like reacher sticks or electric outlet extenders could eliminate the need make risky bending movements and thus prevent falls so commonly associated with these tasks. Many assistive devices designed to aid in various ADL tasks fall into this category and can play an important role in enhancing and extending function for a great many well older adults.

Level II interventions would be most appropriate for those frail elderly with one or more chronic condition. According to The National Center for Health Statistics (Feller, 1983), over 2 million persons 65 years of age and older need help with basic daily activities because of a chronic health problem. The most common of these conditions include arthritis, heart disease, Parkinson's Disease, and arteriosclerosis. Older adults in this category have often had some contact with the rehabilitation system and have used devices specific to their condition. For example, many older adults with arthritis of the hip or knee have used canes, walkers and wheelchairs to augment mobility. However, these people rarely have been provided with devices that could intervene in situations where one or more multiple chronic conditions multiplicatively interact with age-related declines to produce difficulty with daily function. In other words, a comprehensive approach is missing for this group of older adults.

A large number of elderly fall into the category of Level III interventions. These interventions are very intense and most often include a great deal of human service provision together with medical oriented devices. Routinely, when elderly reach this level of need they are often institutionalized in nursing home settings. However, with increases in the cost of nursing home care and decreases in financial assistance for this care, various alternative home based programs are increasing. (e.g., Humphreys, Mason, Guthrie & Liem, 1988).

Who Pays for Assistance for Older Technology Users?

Funding for assistive device technology for older users follows much the same pattern as standard systems that fund children and adults. Medicare, Medicaid, private insurance companies, and HMO's are the primary resources. Again, as with the other age groups service providers are getting better at writing the documentation needed for reimbursement through these services. Many large non-profit disease oriented organizations provide specific funding for assistive technology. For example, local and national Arthritis Foundations provide walkers and canes to persons who cannot otherwise afford them. Unfortunately, these providers cover primarily those persons who typically fall into the more intense levels of intervention. Moreover, many ADL related devices are not covered in any way. Hence the large group of older persons who could benefit from preventive assistance have very little chance of getting reimbursed for devices. Unlike the case with disabled children, there are nearly no private groups that include devices as part of their gift to elderly services (Generations,Summer, 1983 - Special Issue on Services for Elders). In like manner, most older persons in need of technology assistance do not qualify for funding from many of the employment related systems. As was mentioned earlier, most of those systems provide for prosthetics or medically necessary devices. This covers few of the devices that can significantly impact daily task performance.

Who Provides Technology to Older Consumers?

There is no lack of information regarding assistive technology for older adults. Systems like ABLEdata allow anyone to access a computerized data base of over 14,500 products manufactured or distributed by over 1,773 companies. ABLEdata provides assistance with the use of this system. The National Rehabilitation Information Center (NARIC) produces ABLEdata and many additional resources, several of which are free of charge (Karp & Lucas, 1986). In addition, there are increasing numbers of catalogs and self-help books available for use by service providers and consumers. However, it is still the fact that in many cases, the transfer of this information is mediocre at best.

In order to understand technology and information transfer for older users it may be best to view the technology delivery system again, from the level of intervention viewpoint. For Level II and Level III users, the delivery system primarily consists of physicians, occupational and physical therapists and social service providers. The best informed of these groups are the OTs and PTs. Unfortunately, they are often the least seen by older persons. Elderly with specific conditions often are referred to an OT or PT in the late stage of an acute condition. Appropriate devices for these conditions are recommended but little follow-up is ever included in the system. Social service providers often provide intensive long term case management but rarely are familiar with assistive devices for independent living. They most often rely on more traditional human service provision. Physicians are in a unique position to provide referrals for information on assistive technology, particularly to their patients with chronic conditions. Unfortunately, few physicians are well informed on assistive technology. Device suppliers are often in the position to provide information on a variety of devices. Unfortunately, these providers know a considerable amount of information about their products but very little information about elderly and what products are most appropriate for older users.

The large group of healthy older adults are those who benefit least from assistive technology. There is very little attempt to educate this group as to the important role devices can play. To be fair, the blame does not lie entirely on the delivery system. As a group, the elderly have strongly resisted the label of disabled, and unfortunately, this is the exact image that most assistive device technology carries. Ironically, a vicious cycle of technology wasting continues. Device designers do not have incentive to produce better and nicer designs when the older consumers do not seem to be a viable market for these products. In concert, older consumers continue to be reluctant about buying products that carry a medical, disabled connotation. It is clear that this cycle must be broken in order to get devices into the hands of older adults.

A related problem in the delivery system is ubiquitous across all age groups. Suppliers are not highly visible and very little training is included in a product purchase. There are a number of devices on the market that simply are not appropriate for all users (Clark & Gaide, 1986). Knowing which devices work for which people is information that often falls through the cracks of the system. In summary, a comprehensive approach that involves interdisciplinary input from the various professional fields and strong educational programs for providers and consumers is a must if we are ever to realize the goal of providing adequate technological assistance to daily living for our elders -- our future selves.

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TECHNOLOGY TO ASSIST PHYSICAL FUNCTION AND AID INDEPENDENT LIVING FOR CHILDREN AGES 0 TO 21

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INTRODUCTION

One method of analyzing the service delivery system for assistive device technology is according to age groups. Although this is an arbitrary method of organizing services, it somewhat parallels major life tasks. Other service delivery systems for persons with disabilities in the United States also use age delineation to organize services. Examples include the public school system, vocational rehabilitation, and social security. The purpose of this presentation is to discuss the service delivery system for assistive device technology with children from birth to 21 years.

The term "technology" implies a universe of assistive devices ranging from ordinary eye glasses to a sophisticated sip-and-puff controlled power wheelchair. One operational definition of "assistive device" includes compensatory strategies and adaptive equipment (7). The purpose of this technology is to enhance independence in educational, vocational and daily living activities by improving the functional capabilities of persons with disabilities. Thus, an assistive device can be an orthosis or prosthesis that enhances functional capabilities or compensates for functional limitations. However, assistive devices can function differently. Adapting a microcomputer to speak the display provides a blind student access to on-line information in real time without waiting for translation to braille or audio medium.

Application of assistive device technology is a complex process that must address how the device will meet the needs of the individual child. The first and most critical consideration is whether another type of intervention would help the child improve or gain the skills necessary to meet the identified needs. This is important because children possess central nervous systems receptive to learning and can respond with remarkable progress to certain treatment programs. Any assistive device that interferes with this type of progress is obviously contraindicated, such as using a contoured seating system for a two year old child working on developing sitting balance. Other factors to consider are available funding resources, the types of organizations that provide service, and the components that comprise a model service delivery program.

FUNDING RESOURCES

Funding for assistive device technology can mean supporting the purchase of a prescribed device for an individual or financing programs/projects which provide service. This paper focuses on funding mechanisms available for an individual in need of technology.

Federal and State Funding Programs

There are several programs funded by federal and state governments that directly or indirectly support the purchase of assistive devices for children (2). The most comprehensive of these programs is the Education of the Handicapped Act (PL 94-142). This law mandates a free appropriate eduction in the least restrictive environment for all children with any disability from birth to age 21. The federal government provides funding to state education agencies according to a formula which includes the number of handicapped children served in schools. The type of disability or level of services needed has no connection to the money states receive for each student identified as handicapped. Federal funds only cover a small portion of the total cost for each child's special education program. State education agencies then assume the responsibility for funding all special education programs, such as related therapy services and transportation. If included in the child's Individual Education Plan (IEP), schools must ensure that an assistive device is provided for an individual child. However, if the assistive device is purchased by the school, it becomes the school property. This means school personnel retain the right to decide how, when, where and who can use the equipment. There are other problems related to identifying how schools fund technology because there is variability between [illegible]es in their implementation of PL [illegible]-142. For example, the Maryland State Department of Education does not address funding of assistive devices in their state plan. Instead, Local Education Agencies and individual schools are responsible for including funds for this technology in their budgets. In contrast, the state of Pennsylvania funds some assistive devices through their Special Education Resource Centers and has developed the Assistive Device Center to manage the distribution of this equipment. As parents gain more experience in utilizing special education services, it is likely that schools will have to better clarify their role in the transfer of assistive device technology.

Another major program is the Developmental Disabilities Act which funds state services for persons of any age with developmental disabilities. State agencies are responsible for distributing these funds to institutions, day programs and project grants. Funding of assistive devices can be a line item in the budgets submitted by individual agencies. This means each agency is responsible for developing its own policies toward provision of assistive devices, resulting in a variety of service delivery methods. Although children with developmental disabilities are eligible to receive services through these programs, there are no clear guidelines to access funding for assistive devices. In many states, this means equipment is simply not provided.

Other programs available to children such as Medicaid and Crippled Children's Services (CCS) are means tested because funds are intended for the categorically needy. These eligibility criteria require that other financial resources be exhausted and that the device be prescribed by a physician. Medicaid imposes limits on the amount of funding for various assistive devices. CCS varies widely from state to state. In Maryland, CCS only funds requests from specified cooperating agencies. These types of resources are purposefully designed to limit access to available funding.

Individual Initiatives

Parents' financial resources often determine the equipment that children with disabilities will receive. Available resources may cover the entire amount or only part of the total cost for recommended assistive devices. The first resource to explore is the family's personal medical insurance. Reimbursement for assistive devices may be available from health insurance companies with a physician's prescription, prior approval and if the assistive device functions similar to an orthotic or prosthetic device. However, criteria for what qualifies as an assistive device varies between insurance companies and coverage for assistive technology varies tremendously between different group health plans. For example, not all insurance companies or group plans reimburse for augmentative communication devices.

Other funding resources are available through social service clubs, organizations and foundations that make donations for equipment purchases. This approach demands individual initiative to explore appropriate organizations, both within the community and nationally. One supportive organization in the Mid-Atlantic region is the Society for Handicapped and Underprivledged Children. Directories that provide listings of these organizations may be the first avenue to explore for those without experience in this area of funding.

SERVICE PROVIDERS

The transfer of assistive device technology to children involves those organizations involved directly as well as those offering support services. Direct service providers include public schools, medical facilities and parents/advocates. The organizations that provide indirect services are manufacturers, vendors, and professional associations.

Although the public school systems serve all children with disabilities, the majority of these children have limited access to assistive devices. Typically schools and/or teachers must plan for purchase of assistive devices in their budgets each year, perhaps before knowing their students' needs. This encourages purchase of generic assistive devices which have the capability to be adapted to suit individual needs. Examples include modular toilet seats and sets of adapted eating utensils. Although some children can be accommodated in this manner, the assistive device may be available only while a child is in school or in a particular class. Limited access to appropriate technology may interfere with successful application of an assistive device (6).

In the context of a school environment, there are many allocation issues that confound the delivery of assistive devices to children. The most confusing issue concerns the different professionals who may be involved with an individual child. Because funding for aids and associated services comes from various sources, there are no clear, consistent guidelines about who is responsible for supporting the delivery of assistive devices. This means some adapted equipment may end up in closets and some children may not get the technology they desperately need.

Another group of service providers includes hospitals, clinics, university affiliated facilities and private practices offering expertise in rehabilitation technology. These types of medically related services can provide custom, individually tailored prescriptions for assistive devices. These prescriptions may entail planning how to apply a recommended assistive device within an educational context given the proportion of time a child spends in school (4). Typical funding sources for these services include third party insurance companies, Medicaid, and CCS (3).

Although the notion of parents as service providers is new, it has potential to grow and exert a positive effect on improving service from other providers. Observations and reports document how some parents have developed technology applications for their sons and daughters. These parents participate in professional conferences and computer user groups to gather information concerning potential technologies. The development of organizations like Closing the Gap, which evolved from the concern of two parents, reflects the strength of parental involvement.

Manufacturers, vendors, and professional organizations offer indirect service in the form of information dissemination, training, and consultation. Some vendors may provide equipment loans for a trial period and assistance in obtaining funding. Professional organizations engage in lobbying efforts to support desirable legislative proposals and in research to investigate the effectiveness of different assistive device technologies.

COMPONENTS OF SERVICE DELIVERY

Assuming availability of a funding resource and a service provider, there are four basic components of service related to the delivery of assistive device technology. A brief review of the literature indicates agreement in identification of these four factors (1)(4)(5). The first component is training because it is the most critical (8). Training occurs **throughout** the process of service delivery, for the professional, the child and the family. The professional needs training to keep up-to-date with assistive device technology while the child and his or her family needs to learn how to use the recommended device. Successful training strategies incorporate multiple media to support the use of technology. Some examples include printed material such as manuals and newsletters, videotapes, experience oriented workshops, professional networks, and troubleshooting resources available through toll free phone numbers and on-site visits.

The next component involves assessment and evaluation to determine the most appropriate assistive device(s) to meet a child's needs. A thorough evaluation relies on the availability of a wide array of adaptive equipment for trial purposes. One program has established the equivalent of a lending library to provide both hardware and software resources (5). Another program has manuals and videotapes to help professionals with systematic assessment to identify augmentative communication needs (1).

Service directed toward the implementation phase usually involves training the user and significant others application strategies. The extent and type of training may depend on the complexity of the recommended assistive device. For example, implementation of a universal cuff to assist with self-feeding is simple in comparison to implementing the use of a wheelchair operated environmental control unit. This is because implementation requires learning how to operate the assistive device as well as how to use the aid effectively in different situations (8). With more advanced technologies the implementation phase becomes more critical to the success use of the device.

The final component is follow-up services which include on-going evaluation and technical support services. As children develop and progress, their needs change. This warrants particular attention to monitoring the appropriateness of an assistive device. Although this phase is often neglected, many follow-up issues can be addressed by thorough training during implementation and by less time intensive methods such as telephone consultation.

SUMMARY

What distinguishes the transfer of assistive device technology to children is the service delivery systems involved. The assistive devices applied with children are the same technologies as adults use in many cases. However, children use these assistive devices for different purposes. A power wheelchair may allow a child to play outside with his friends while an adult may use this as his means of mobility at work in a large office. To obtain appropriate service, parents must understand the complexities of service delivery system that provides assistive device technology. Parents who are familiar with the spectrum of funding resources and are knowledgeable about service providers located in their region are the most successful consumers.

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HOW ADULTS WITH DISABILITIES GET THE EVERYDAY TECHNOLOGY THEY NEED

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There is increasing recognition of the importance of technological support for an adult with a disability. When technology for a disabled adult is considered, priority may be placed on equipment that can be used as a means to employment, either directly through worksite adaptations, or indirectly by enabling the individual to get to work. But beyond specific applications like employment, technology should be part of a support system that enables an individual to do regular everyday tasks and participate in routine daily activities. It should fit the needs of the individual, changing as expectations and requirements change. In many cases appropriate technology will enable the individual to achieve a healthy sense of self respect and a degree of independence that can result in an ability to more effectively integrate into mainstream society.

"Technology for independent living", as stated in the overview paper for this session, is that pervasive supporting technology which is needed to underpin the routine activities of daily life. In exploring the delivery system for this technology, to start with we should ask:

Are people getting what they need?
In the words of a disabled activist: "I am a pushy person but I have given up so many times in even trying to find the technology I think I might need just because it is such a hassle. In 1986 I realized that I needed a lot of new equipment: an electric hospital type bed, a new wheelchair for traveling and work, a new seat, a computer that I could use, an accessible workstation. I also wanted to see if I could drive now. Ten years ago I was evaluated as being unable to easily drive and now I'd like to see if anything is available that would make driving feasible. I'd been getting really concerned because of increased pain and loss of muscle control, especially while typing. It was beginning to effect my work. But I was worried about (1) how I would identify what I really needed and (2) who would pay for it. One night I woke up and realized that I should go to the Department of Rehabilitation for post-employment services. I knew that nothing I needed was a luxury. My friends laughed when I told them I was going to the state agency. But I had finally realized it was this agency's responsibility to help me. I have a right to these services and I wasn't going to let them say no to me." This individual didn't even think to include modifications or devices to make the bathroom and kitchen more accessible to her, nor an environmental control system that would enable her to lock her doors when her attendant leaves at night. Furthermore, her friends with disabilities and similar technology needs are all watching to see what happens as she takes on the system. If she makes it work, they will try to also.

THE INFLUENCE OF THIRD PARTY REIMBURSEMENT SYSTEMS

Although a great deal of supportive technology is bought and paid for out of pocket, third party reimbursement still drives the system. Disabled adults are primarily affected by the various health insurance schemes (Medicare, Medicaid, private/group plan health insurance), compensatory insurance schemes (worker's compensation, long term disability, personal injury/liability, veteran's benefits), vocational rehabilitation schemes related to employment, and income subsidy schemes. There is an emerging set of financing mechanisms, some subsidized, some not, which an employed adult might use to purchase equipment; and there are always the schemes related to philanthropy/good will (voluntary health organizations, service clubs, special event fundraising, churches), though these are often more ready sources for children.

Medical/Health care systems:
The current delivery system for assistive technology is based in or heavily influenced by the medical model and its focus on sickness. To prevent abuse in the medical system, policy has tried to ensure that services and equipment would not be desirable

to non-sick people. The people who need assistive technology often do not fit into this model well. Most are not sick, yet they need compensatory technology to achieve equity with non-disabled peers.

It is interesting to note that Medicare, though designed to provide for acute medical care needs of older adults, is a prime determinant for technology reimbursement for adults of any age. Both private insurance and the state medical assistance programs (Medicaid) frequently use Medicare's reimbursement guidelines for equipment as models for their own coverage decisions. This is indeed unfortunate, because Medicare carriers generally exclude coverage for almost all technology for independent living as "hygienic items" or "convenience items" or "nonreusable disposable supplies". Medically related items such as a respirator, continuous passive motion device, or crutches are more likely to be covered. The Health Care Finance Administration (HCFA) which administers the Medicare program provides minimal coverage guidelines for most assistive technologies, and specific decisionmaking is generally at the level of the local or regional fiscal intermediary or carrier; decisions are rarely made on the basis of a consistent national policy, and they vary widely from contractor to contractor. Yet Medicare sets the tone for coverage decisionmaking! Medicare prohibits payment, by specific statutory language, for "hearing aids, glasses and dentures". There are other types of equipment that are consistently denied. It has become a standing joke in home health care, that Medicare stops at the bathroom door -- items like grab bars, a raised toilet seat, or shower chair will not be authorized for payment. If a case can be made that a device is a prosthesis, coverage is sometimes authorized. This has happened in a few cases for communication aids. Cochlear implants are now covered, they are prosthetic. Hearing aids cannot be. Since independent living technology is rarely a prosthetic replacement, it is routinely denied. It becomes "ungettable," people stop asking.

The medical/health care system is not a very effective system for procuring supportive technology, but it does fund some of it. Common sense and practical experience tell us these are not really medical appliances. However, it is dangerous to acknowledge that these devices are not really health care/medical technology. Much of the third-party reimbursement for them is based on meeting the criterion of "medical necessity," which can differ from one agency to another. Unless health care is extremely broadly defined, it takes a real stretch of the imagination and the creative writing skills of a funding seeker to consider many of these devices "medically necessary." The fact that the documentation to justify reimbursement for these tools for living in the community must be couched in terms of medical need further reinforces the medicalization of community-based living needs in the minds of health professionals, funding agencies, and the "patients" themselves. Until alternative funding can be developed that allows recognition of the real nature of this necessary and cost-effective equipment, we are forced to use language that reinforces a medical model.

Until we are able to drop the myth of medical necessity, it will be difficult to discuss, for example, mobility devices as functional tools for getting from one place to another, rather than as pieces of therapy equipment. An additional negative effect of the myth is that there is no incentive or understanding of the need to design "therapy" equipment to be narrow, lightweight, aesthetic, or comfortable.

Employment Related Systems:

The system that supports employment is unique to adults. Although the vocational rehabilitation (VR) system can provide services as young as age 16, and does provide post secondary educational and training opportunities, the primary emphasis is on adults. It is generally difficult to get services if one is over 55, though the agencies have mandate to serve older individuals.

Theoretically, the federal-state VR system can provide any technology that can be shown to be of value in preparing an individual for employment, or in maintaining that employment. In practice this is not always the case, and the interpretation of need is very narrow. The Rehabilitation Act Amendments of 1986 added additional emphasis on the provision of rehabilitation engineering services, but qualified it with the clause "where appropriate." There were no additional funds appropriated for this specifically mandated service; and yet these technology services are exempted from a similar benefits search. It is unlikely that the Rehabilitation Services

Administration (RSA) will issue specific regulations interpreting this new section of the law. It is hoped that they will at least provide the state VR agencies with some guidelines for implementation. There is currently considerable confusion as to what the state VR agencies could and should be doing to meet this new obligation.

The VR system, with is focus on employment, has traditionally focused its attention on shorter term and/or time-limited types of interventions. However there is now an increased recognition of the importance of ongoing, coordinated support systems such as independent living and supported work. Technological support services and systems play an important role in these new trends. However, there has only been a single generation of severely disabled persons who have benefitted from significant technological intervention. We are only now beginning to get a sense of the longer term issues that a comprehensive support system must address. There are many unanswered questions related to the rehabilitation agency's role when former clients find they need upgrading, replacement and financing for subsequent generations of equipment, and to the limits of typical coverage for assistive technology for clients in their active caseloads, e.g., should there be routine coverage for assistive technology that may be only used in the home, because without it the individual does not have the supportive base to stay competitively employed?

Other employment related service systems based on compensatory insurance schemes tend to take a broader and more long range view of the supportive technology their clients require. They will often provide the equipment and adaptations that are needed in the whole range of life activities, so they can make the earliest possible case settlement, and/or get the individual back to productive work and off their roles.

The system that provides for veterans with service-connected disabilities could be viewed as a compensatory system related to employment. This system bears further investigation, because, although it has major flaws for eligible beneficiaries, it seems to provide supportive technology and other services in a more comprehensive fashion. VA policy has tended to be that blind veterans would be provided with all necessary services and devices to overcome their handicap, and other disabled veterans could receive technologies deemed medically necessary. However, the VA seems to define "medically necessary" much more broadly than most of the other systems, and they have had long standing coverage for home adaptations, adapted vehicles, etc. for veterans with service-connected disabilities.

PROBLEMS WITH THE EXISTING SYSTEMS

The systems that are operative in providing either the equipment, the related services, the funding or the information about this kind of technology are not coordinated. The compartmentalization as it relates to technology results in levels of benefits, and layers of complexity, that preclude a disabled person from living life comparably to a non-disabled person.

Systems do not do outreach to people to say we recognize that technology can be a beneficial part of your life and therefore we will help you determine what you need, help you try it out, learn how to use it, and find ways to pay for it. Additionally, when you get equipment there is little if any discussion about the frequency you will need the equipment replaced. Yet we know that appropriate technology can in many cases deter one's disability from becoming more severe. From my personal experience, while I have had a curvature of my spine for my entire life, the only technology ever discussed was bracing. I have used a wheelchair for 36 years, and only this year have I gone to a program for seating evaluation. Despite my pelvic obliquity, no doctor ever suggested that appropriate seating was important. I had to get a doctor's note (i.e., a prescription) before the evaluation could be authorized and the customized seat and services could be reimbursed.

Speaking as a consumer: So much of the system is based on excluding us. We need a system that does some form of assessment, then provides us with what has been acknowledged that we need. There is virtually no outreach, no information to the people who need the technology. The professionals aren't really acting as advocates or as adversaries, they just don't understand what is available or what it could do for us.

We don't know what technology can do for us. We don't know what to ask for. We don't even know we should ask. We don't dream or we've stopped dreaming. Dreams for us are things that the average able bodied person takes completely for granted, e.g., getting up in the morning and taking a shower, going to the store or to a friend's house without a lot of preparation. We have to justify that everything we need must either be medically necesary or employment related, as if that were the extent of living. We don't get what we need; if we are lucky, we may get what is gettable. Furthermore, there is still a strong medical bias that if we use technology, we are failures.

TOWARD A MORE APPROPRIATE SYSTEM

The next steps that are needed include: increasing awareness of the benefits and availability of technology: guidance in incorporating technology into existing programs; and training and interpretation for all participants involved about the role technological support can play. There should at least be enough information, outreach and coordination to provide disabled adults with the expectation that appropriate technology and related services are available, that suitable solutions can be found, and that they have the right to assistive technology that is equivalent to an able bodied person's basic support systems.

The system should provide for the average disabled adult: easy ability to comprehensively identify personal needs for technology, to review the technology that exists in the field, and the ability to purchase equipment so that costs do not produce an inequitable hardship for the disabled person.

The resource allocation issue of whether or not assistive technology is a luxury or necessity is really an issue of equity: a disabled person should not have to pay more than an able bodied person to achieve comparable norms in functional abilities, lifeskills, or lifestyles. The self reliant American approach steers us to take care of ourselves/our families. However as our lifespans increase, our ability to save the lives of infants, and traumatically injured improves, we are as a nation being faced with the recognition that the individual/family may need to bear some extra costs, but that those costs shouldn't be catastrophic. Our tax codes reflect this philosophy, e.g., only after we have spent 7.5% of our taxable income on medical expenses, can we deduct any additional expenditures.

When looking at setting up a system for assessment, funding and maintenance on technology it is essential that we look at training health care professionals and consumers regarding how to use, order, pay for and maintain the equipment, as well as knowing how and when to reevaluate its effectiveness and replace it when necessary.

PREPARING FOR THE FUTURE

As the independent living movement gains momentum, we expect to see more severely disabled adults realizing that they have a right to assistive technology beyond the narrowly constrained medical and employment models. The demand for technology related information, services, and equitable reimbursement will probably reach crisis proportions. Assistive technology is likely to figure more prominently in long term care discussions especially as they relate to community based care. A generation of disabled students is reaching adulthood, and though they did not benefit much from the everyday assistive technologies as kids, they have felt the effect of technology in at least some aspects of their educational process.

ACKNOWLEDGEMENTS

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THEME SESSION/ SESSION THÉMATIQUE R

Recreation
Récréation

'PERSONAL TECHNOLOGIES FOR RECREATION - AN OVERVIEW OF SPORTS PROSTHETICS AND ORTHOTICS'

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The advent of recently developed products which are commercially available enable today's physically challenged person to participate in sports and recreational activities with greater ease and success. Although persons who wear prosthetic and orthotic devices have participated in sports and recreational activities for many years they have done so in spite of equipment that was originally designed to accommodate only average daily living activities. In many cases the physically challenged person would make adaptations in sports technique through gait or body positioning to participate, many times enduring great pain due to the lack of existing technology.

Physically challenged persons who wanted to participate in a special sport for which there was not a commercial device available would either design their own or work with their prosthetist/orthotists to make a custom part for the particular situation. Over the years the consistent requests from patients who wanted to run, swim, ski, etc., have focused the attention of many medical professionals, engineers and manufacturers who have only recently started to address the needs of the sports minded physically challenged person. Although several devices now exist commercially for sports oriented physically challenged persons, many are still made on a one-to-one basis with the close relationship of the prosthetist/orthotist. Many advances in lightweight materials and energy storing devices are proving to be beneficial to geriatric/non-athletic patients who, by using these innovations, are accomplishing their daily activities with greater ease.

LOWER EXTREMITY PROSTHETICS

Running

Prosthetics Research Study in Seattle, Washington, conducted a study surveying 100 lower extremity amputees[1]. It concluded that running was the hardest activity for amputees. This prompted the **Prosthetics Research Study** to investigate this further by collaborating with the University of Washington's Kinesiology Department to study the way in which amputees run[2]. The lacking component for running was the gravitational forces necessary to propel the amputee forward through the active plantar flexion necessary at toe off. Together with a team of engineers from Boeing, the **Prosthetics Research Study** began to develop an energy storing foot to enable amputees to run more effectively. The foot which has been commercially available since October 1987 is called the SEATTLE Foot[3]. It is cosmetically detailed to mirror the anatomy of the foot and has been widely accepted around the world with nearly 20,000 units sold to date. Since that time other energy storing feet have followed from several manufacturers who also recognized the benefits that energy storing feet have for amputees who wish to run or walk with greater ease.

The Carbon Copy II[4] is another design in cosmetic energy storing feet which also contains a spring keel device. Both feet have been widely accepted on a variety of amputees above and below the knee. The Stored Energy Foot (STEN Foot)[5] has also received attention for its energy storing keel. This foot offers a limited amount of stored energy compared to the other feet. It does offer the widest selection of heel heights for a variety of shoes and provides a smoother and softer roll-over from heel strike to toe off.[6]

One of the most different type of feet available is the FLEX FOOT. This graphite composite provides a lightweight prosthesis that allows for great energy storing possibilities. "Unlike any other component currently available, Flex-Foot™ utilizes the entire distance distal to the socket for function. Since it stores energy throughout its entire length rather than just within a four inch keel, the results are a very responsive and resilient component."[7]

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[1] B. Kegel, J. Webster., and E.M. Burgess,: Recreational Activities of Lower Extremity Amputees:
A Survey. Rehabilitation Literature, Vol. 41, No. 9-10, pp. 98-102, 1980. ABSTRACT.

[2] R. Enoka, D.I. Miller, E.M. Burgess: Below Knee Running Gait. American Journal of Physical Medicine, Vol. 61, No. 2, pp. 66-84, 1982.

[3] Model & Instrument Works, Inc., 861 Poplar Place S., Seattle, Washington 98144.

[4] Ohio Willow Wood, P.O. Box 192, Mount Sterling, Ohio 43143.

[5] Kingsley Manufacturing Company, 1984 Placentia Avenue, Costa Mesa, California 92627

[6] John Michael: Energy Storing Feet: A Clinical Comparison. Clinical Prosthetics & Orthotics, Summer, 1987.

The alignment of the prosthesis can vary the energy storing capabilities of these feet and can be set by the prosthetist for either running, walking or somewhere in between to accommodate most activities. Children's sizes are not available in any of these previously mentioned feet. The smallest size offered begins with a size 5 women's.

Amputees have been able to successfully use the energy storing feet to run with a more normal gait along with greater comfort. It has enhanced the ability to participate in sports which require running as a key ingredient for success along with enhancing everyday activities of daily living.

Socket Design

The most important component in the design of a sports prosthesis is the comfort and function of the socket which fits over the residual limb. All amputees can now benefit from the use of clear plastic diagnostic sockets which allow the prosthetist to observe the dynamic and static effects of the patient's residual limb. Incorporating the use of Alginate in the clear socket help to ensure total contact. The above knee amputee may find greater comfort in the narrow M/L design socket also known as CAT/CAM[8] or NSNA. This socket design is quickly replacing the quadrilateral socket for many amputees. Because the ischial tuberosity does not support the weight of the amputee on a posterior shelf of the socket the narrow M/L is more comfortable. The ischial tuberosity is contained within the socket and the femur is stabilized and held in adduction through the narrow M/L design. This socket proves to provide a more anatomical and physiologically improved concept for many above knee amputees. Many above knee amputees are able to run with a foot-over-foot gait by this variation in socket design.

New materials are being used in the construction of prostheses from graphite, flexible thermoplastics and silicone. The limbs are lightweight and new fabrication techniques and materials reduce the patients' energy expenditure and reduce skin friction when properly fit.

General Sports/Recreational Considerations

Some components such as energy storing feet are commercially available for running. In many circumstances, commercially available components are not necessary or available. The prosthetist can custom design a specialty limb for a variety of sports such as bike riding, skiing, swimming, rock climbing, and boxing from existing materials at his facility or at a local machine shop for special patient needs.[9]

The commercially available axial rotator has been used to relieve the residual limb of torque and is most effective for the amputee golfer. The below knee and above knee golfer can have this device incorporated into their prosthesis which particularly assists the golf swing as well as everyday activities.

Upper Extremity Prosthetics

The unilateral upper extremity amputee can certainly participate successfully in a variety of sports without his prosthesis. Many activities can be enhanced through the use of a prosthesis to create greater body symmetry and positioning for the best execution of each sport skill.

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[7] Ibid.

[8] John Sabolich: Contoured Adducted Trochanteric- Controlled Alignment Method (CAT-CAM): Introduction and Basic Principles. Clinical Prosthetics & Orthotics, Vol. 9, No. 4, pp. 15-26, Fall, 1985.

[9] Albert F. Rappoport, Proceedings from the 16th National Conference on Physical Activity for the Exceptional Individual "Recent Developments in Sports Prosthetics for the Lower Extremity Amputee," October 24, 1987.

The intimacy of the socket design, materials and alignment are all critical to the success of the upper extremity amputee's approach to sports and recreation.

Over the years a number of custom individual designs have been tailor-made by the prosthetist for sports and recreation use. However, some commercially available terminal devices can also be employed to enhance the amputee's function.

The Bowling Attachment, Baseball Glove Attachment and Ski Hand are available from Hosmer Dorrance Company.[10]

The Voluntary Closing Terminal Device and the Super Sports Hand are available from TRS, Inc.[11], and used in a wide variety of sports applications. The Amputee Golf Grip is available from Recreational Prosthetics Inc., in North Dakota.

EXTRA AMBULATORY CONSIDERATIONS

The adapted physical educator or therapeutic recreation specialist working with the training of amputees should be aware of the prosthetic modifications for sports participation in order to achieve the maximum benefit from their training/ teaching methodologies. Since many times a special sports prosthesis is a luxury item a dual purpose limb for several sports activities and walking may be a consideration in the prescription criteria. Children and adults need to learn to monitor their own activity level so skin irritations do not occur in the form of blisters which may prevent further participation due to pain. If a blister does occur skin care products are available to relieve pain and aid healing.[12,13] The changing of a fresh stump sock can be imperative during heavy activity when heavy perspiration occurs. Extra suspension aids can be used on the prosthesis when participating in extra ambulatory activities. The addition of a waistbelt, latex suspension sleeve or Silesian Bandage can be most helpful. New or existing prostheses can be made waterproof for water sports.

SPORT ORTHOTICS

The area of sports orthotics has, for the most part, been associated with varsity, collegiate or professional athletes who have either suffered injuries or wish to prevent injury. We have seen sports orthotics used to fill ski boots, runner's shoes and a variety of other footwear to provide the proper compensation for various foot deformities. Knee orthotics are many times used by athletes for prevention of injuries as well as rehabilitation of various injuries, particularly those of football players and skiers in both amateur and professional rankings. Sports orthotics utilizes a variety of brace designs to compensate for and/or support various deformities. They are also used to prevent disabling injuries along with the rehabilitation of injuries to allow the athlete to participate once again in the activities enjoyed before injury.

For the long-term disabled person, either with cerebral palsy, paralysis, multiple sclerosis, polio, etc., the term sports orthotics may have a different meaning. The braces and devices that these persons use may not be specifically used just for sports participation. Orthotics designs can now incorporate sports designs with their everyday brace for average daily living. Designing the criteria needed for their sports participation should be discussed with the patient and taken into consideration before a new brace is designed.

Weight Considerations

One of the considerations to make when designing a dual purpose brace for average daily living activities and sports participation would be weight. There are a number of carbon fiber, titanium, thermoplastics components, etc., which can be used to replace many of the metal and leather parts previously associated with bracing of the upper and lower extremity.

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[10] Hosmer Dorrance Corporation, P.O Box 37, Campbell, California 95008.

[11] TRS, Inc., 1280 - 28th St., Suite 3, Boulder, Colorado 803203-1797

[12] Spenco Medical Corporation, Box 8113, Waco, Texas 76710.

[13] Johnson & Johnson Products, Inc., (Bioclusive®), New Brunswick, New Jersey 08903.

Strength

Strength is also a high consideration when designing a dual purpose brace because many times the materials that were used for average daily living activities will be stressed much higher when the user is participating in sports. Therefore, critical stress areas should be analyzed depending on the sport activity, and the weight of the person. Each component is custom-made with varying carbon fiber lay-ups or selectively placing reinforcement in the plastics and choosing metal components to the proper strength grade for each application. Many off-the-shelf titanium parts can be found which offer a high strength-to-weight ratio as well as carbon fiber components.

Heat Dissipation

Heat dissipation is also a major factor when designing a brace used for extra ambulatory activities. This can be varied with different types of thermoplastics, inserts and synthetic materials, however, in many cases leather is still superior to many of the synthetics due to its breathing characteristics and compatibility with the skin. When using thermoplastics holes can be selectively drilled to provide the patient with some ventilation.

Dual Purpose Considerations

Donning and doffing the brace with Velcro straps or quick release buckles as seen on many sports braces are quickly replacing many of the old leather straps and buckles commonly associated in the orthotic industry. A brace used for everyday activities as well as sports may be well suited with these options. In certain cases the long-term physically challenged person may choose to have two braces, one for a particular sport activity, such as a waterproof one for swimming or one that may have to be strengthened to higher requirements above his daily living activities.

Materials and design are changing rapidly in the area of Sports Orthotics to allow both the athlete and long-term physically challenged person a wide variety of options from which to choose when selecting the proper brace for sports activities, average daily living activities or both.

Conclusion

The continuation of sports organizations for the physically challenged[14,15,16,17,18] is most helpful in training those with a recent disability to participate in sports once again. We are all well aware of the benefits sports provides the physically challenged. The prosthetic/orthotics user now has the components to allow participation in a wider variety of sports and to achieve higher limits of endurance and strength. The fit of the prosthetic/orthotic device becomes more critical now as higher demands are placed on it. It is hoped that as the area of sports prosthetics and orthotics develop the physically challenged person will be seen more often than not engaged with the able-bodied head-on in competition in the mainstream rather than only with physically challenged counterparts. This will only be possible if manufacturers, engineers, physicians, therapists and prosthetist/orthotists continue to work together in a team effort to assist physically challenged persons with the proper training and components to be the best they can be.

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[14] National Handicapped Sports and Recreation Association, 1145 - 19th Street, N.W., Suite 717, Washington, D.C. 20036.

[15] United States Amputee Athletic Association, Route 2, County Line Road, Farview, Tennessee 37026.

[16] National Wheelchair Athletic Association, 2107 Templeton Gap Road, Suite C, Colorado Springs, Colorado 80907.

[17] National Wheelchair Basketball Association, Seaton Building, University of Kentucky, Lexington, Kentucky 40506.

[18] National Foundation of Wheelchair Tennis, 3857 Birch Street, Suite 411, Newport Beach, California 92660.

TECHNOLOGY AS A CONTINUUM FOR RECREATION

by Peter Axelson
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OVERVIEW

Recreation is an important human activity, one often overlooked by the rehabilitation professional, who must first strive to assist a client in meeting his or her vocational or daily living needs. Recreation, however, is really "re-creation": that is, the new creation of physical and spiritual energy, which nurtures the desire to live and grow. Making sure that recreation needs are met is a necessary part of the rehabilitation process.

The use of technology is integral to most modern recreational activities, and is particularly important to make recreation accessible to people with disabilities. Understanding the relationship between technology and recreational activities will assist rehabilitation professionals in addressing the recreational needs of their clients.

This article analyzes recreational activities with respect to the user, commercial recreational equipment, and the environment, and discusses where technology should and should not be applied in each of these areas. Guidelines are offered to assist the rehabilitation professional in analyzing a client's recreational needs, different recreational activities, and the environment in which a given activity is to be performed. The goal of this analysis is to meet the "immediate" needs of the individual and avoid "complex" solutions except where absolutely necessary.

The conclusion of this paper provides some useful sources for specific information on a variety of recreation technologies.

DEFINITION OF TERMS

Individual - with or without disability, a person with a need for leisure or recreational activity.

Activity - passive or active, a moment or process in which the individual recreates.

Environment - the physical space in which the individual performs an activity.

Adaptive Technology - modification to a recreational device or creation of a new device or system that enables an individual to participate in an activity within an environment.

Recreation - the "re-creation" of spiritual, physical and intellectual energy through participation in a leisure activity.

THE NEED FOR RECREATION

Most rehabilitation professionals help to provide technologies to assist people in their daily living or vocational activities. There are several ways to determine what kind of assistance is really needed.

First, if you analyze the activity patterns of a client with regard to daily living, vocational and recreational activities, you will probably see a need to help that individual to reestablish a balance of activities, or to establish a balance that never existed. Second, you might observe the balance of physical, intellectual and spiritual activities in his or her life. A third perspective would be to analyze the level of your client's independence or dependence upon the environment and other people.

Your recognition of the individual's need for recreational activity may be the first step in assisting him or her to develop a more balanced level of activities in their life.

RECERATION AND TECHNOLOGY

Three different types of technologies are relevant to this discussion:

Personal technologies
Activity-specific technologies
Environmental technologies

The relationship of each of these technologies to a given activity, whether it be daily living, vocational or recreational, will be valuable in your assessment of an individual's needs. Furthermore, your ability to define and solve a given individual's problem will be enhanced by your understanding of the uses and function of these differing technologies.

Personal Technologies

What I am calling "personal technology" is hardware that enables individuals to participate in recreational, daily living and vocational activities. Everyone, with or without a disability, uses personal technologies to enhance their abilities. Personal technologies are things that are "worn," such as shoes, glasses, clothes, and so on. Mainstream recreational technologies in this category include items like wetsuits, foul weather gear, down parkas and swimsuits. Personal technologies for people with disabilities are really no different: a wheelchair or a prosthetic limb is a personal technology.

Recreation Technology Continuum

User	Activity	Environment
←		→
Personal Technology	Activity Specific Technology	Environmental Technology

For some recreational activities a specialized personal technology might be required for people with disabilities: a racing wheelchair would be used by a marathon racer; a dynamic prosthesis might be used in an activity such as running by an amputee. There are many examples of personal technologies that enhance the lives of people with disabilities.

Activity Specific Technologies

These are devices and systems which enable an individual to perform **specific** activities. Again, activities with specific technologies are not foreign to John Q. Public. Many of them relate to the individual's needs for transportation, communication, daily living and recreational needs: automobiles, aircraft, bicycles, boats, washing machines, telephones and television are all examples. Activities with specific technologies for recreation would include diving gear, bicycles, tents, parachutes, gliders, motorcross bikes, windsurfers, tents and kayaks.

Path A →	Modification to Existing Activity Specific Technology
Path B Last Resort →	Development of New Activity Specific Technology

Of course, for the individual with a disability, activities with specific technologies may or may not use existing technology. A hand-powered bicycle or a sit-ski are examples of "different" technologies which make possible activities similar to those made possible by the use of "mainstream" technologies. Modifications or adaptations enable people with a disability to use equipment designed for "mainstream" use by people with normal function. Hand controls are one example of a modification to a "mainstream" product, the automobile.

Environmental Technologies

Environmental technologies most often provide for the daily living needs of people, such as shelter, food and water. In general these include things that do not move, like the roof over our heads or the toilet and shower facilities in our bathroom. A kitchen is an environmental technology designed to enable us to feed ourselves. A well and septic system are technologies necessary for our survival as well.

Some examples of environmental technologies for recreation would include the chairlift at a ski area, which enables us to ski in the winter. A pier or dock on a lake is an example of a technology that modifies the water environment for boaters with or without disabilities.

THE RECREATION CONTINUUM

An awareness of the different functions of personal technologies, activity-specific technologies, and environmental technologies can be extremely useful in our work as rehabilitation professionals. This is true in general, and particularly true for recreation applications.

The technology continuum, as it applies to recreation, begins with personal technology. Often, developing some form of personal technology will best enable the user or individual to function within a specific activity. It may be better, for example, to modify a wheelchair to operate in sand than to build a ramp over sand dunes to the seashore. In another case, it may be more appropriate to modify the environment to enable an individual to participate in a given activity, i.e., to build a ramp. Or the most appropriate solution might be to modify an existing "mainstream" activity-specific technology: a joystick with a shoulder interface will make video games accessible to users with certain disabilities, for example. As a last resort we may need to develop a new activity-specific technology that will enable the individual to perform the activity. The mono-ski and sit-ski are examples of this kind of technology since a paraplegic cannot ski using leg braces, skis and boots.

UNDERSTANDING THE NEED

Some important questions to ask before deciding on one or another of these technologies include:

- Who is involved in the activity?
- What information exists about the activity?
- Where can I look for information about the activity in the mainstream as well in the disability community?
- What environment is the activity performed in?
- What are the characteristics of that environment?
- What will be the functional requirements of the individual that wishes to participate in that activity?
- What technologies are normally used to participate?
- Who else is involved in the activity? Are friends, or family involved?
- Does this individual wish to participate independently or dependently in the activity?

Once you have decided which technology is most appropriate for this activity and this individual's special needs, **think simple and immediate**. How could you make this activity possible -- right now? Analyze what could be done by tomorrow, using materials on hand, to make the activity accessible to the person with a disability. Even if the results are not ideal, you will learn valuable lessons which you can apply toward an effective solution. In short, only after trying simpler measures should you seek to create a new, activity-specific technology.

A CALL TO TECHNOLOGY DESIGNERS

The designer of any given technology has made certain assumptions about what the user of that technology could and could not do. Designers in general need to consider designing for a broader range of functional abilities (as European designers have by replacing door knobs with door handles as an architectural standard). When they do, more technologies developed for the general public will be usable by people with disabilities.

The same challenge applies to rehabilitation technologists. We have the opportunity to facilitate the individual's participation in a specific activity. The better, more broadly applicable our design, the more individuals will be served by any technologies we develop.

SOME RECREATIONAL TECHNOLOGY REFERENCES

It is beyond the scope of this paper to review all recreational technologies that are available for people with disabilities. For specific information on a variety of recreational technologies I suggest the following sources:

Journal of Rehabilitation Research and Development-Clinical Supplement No. 1 Physical Fitness Sports and Recreation for Those with Lower Limb Amputation or Impairment
By Bernice Kegel, R.P.T.
Office of Technology Transfer (153D)
Veterans Administration Medical Center
103 S. Gay Street
Baltimore, MD 21202
(301) 962-1800

This publication has photographs and text describing adaptive technologies which enable people with disabilities to participate in recreational activities. A list of sports organizations and resources are included in the publication.

Spinal Cord Injury - A Guide for Patient and Family.
By Phillips, L., Ozer, M., Axelson, P., Chizeck, H.
Raven Press, 1987
1185 Avenue of the Americas
New York, NY 10036
(202) 930-9500

RESNA (Association for the Advancement of Rehabilitation Technology) Technology for Independent Living Sourcebook.
1011 Connecticut Avenue, NW, Suite 700
Washington D.C. 20036
(202) 857-1199

Design for Integrated Recreation
Video tape
Peter Axelson - President
Beneficial Designs, Inc.
5858 Empire Grade Road
Santa Cruz, CA 95060
(408) 429-8447

THE NEED FOR TECHNOLOGY TO ENHANCE AND CREATE RECREATIONAL AND LEISURE EXPERIENCES

Karen P. DePauw, Ph.D.

INTRODUCTION

The need for technology to enhance and create recreational and leisure experiences for individuals with disabilities arises from the basic assumption that individuals with disabilities have similar needs for recreation and leisure as able bodied individuals but that modification and/or adaptations might be required. Technology is but applied science, a technical method of achieving a practical purpose, and comprises the totality of the means employed to provide capability necessary for human function. Inasmuch as quality of life is a concern of able bodied persons, the quality of life for individuals with disabilities can often be enhanced by technology.

RECREATION/LEISURE AND LIFE BALANCE

In the process of creating and enhancing opportunities for recreation and leisure experiences for individuals with disabilities, a continuum of three basic components must be understood: rehabilitation, leisure education, and recreation participation (3). Rehabilitation involves restoration to a condition of health and constructive activity, and improved functional ability. Leisure education includes the acquisition of leisure and social skills, awareness of self and leisure, and knowledge of utilization of leisure resources. The rehabilitation and leisure education of an individual should culminate in Recreation participation which ultimately allows for personal enjoyment through voluntarily selected recreation and leisure activities. These components should be viewed as somewhat sequential and as interrelated parts of the whole of recreation participation by individuals with disabilities.

Whether one views the key aspects of humanness as being depicted by a square (physical, mental, social, psychological/spiritual) or an equilateral triangle (mind, body, spirit), the concept of balance among these key ingredients is critical. Beyond this balance, there is a need to maintain balance among one's vocation, recreation, and activities of daily living (ADL); the time spent at work, at play, and taking care of daily personal needs.

Not only are physical activity and recreation or leisure activities important for maintenance of life balance (physical, mental, social, psychological/spiritual) but perhaps more so for the demands of daily living (vocation, recreation, ADL). Although possible for all persons, imbalance among work, play, and ADL is often more apparent with disabled individuals. With a physical or sensory impairment, the time required for activities of daily living (eg. feeding one's self, dressing, grooming) may be more than spent by an able bodied person. Also, the time devoted to work might similarly increase thus potentially decreasing the time to be allocated for leisure pursuits and recreation. With the pressures of today's society for "making a good living", recreation and/or leisure pursuits are thought to be those which merit less emphasis. Relatively not understood are the benefits of physical activity and recreation/leisure to establish and/or maintain balance in one's life especially for individuals with disabilities.

BENEFITS OF ACTIVITY

Specific benefits of physical activity and recreation participation have been identified in the literature (2). Applicable to both disabled and able bodied individuals, the benefits of physical activity may include the following:

1. Physical benefits such as increased mechanical and physiological efficiency; increased fitness, flexibility, and strength; decrease in heart rate; increased life expectancy; maintenance of motor skills throughout one's life,
2. Mental benefits including reduction of stress, lessened anxiety, increased alertness, continued intellectual stimulation, creativity
3. Social benefits including improved social interaction, increased self confidence in social situations, social acceptance
4. Psychological/Spiritual benefits such as improved self concept and self esteem, inner sense of calm or spirituality, increased self motivation
5. Positive effects found with performance at work such as improved productivity, increased job satisfaction, and decreased absenteeism
6. Increased self sufficiency and motor function for ADL including caring for one's physical needs, grooming, feeding, etc.
7. Obvious recreational benefits occurring from participation such as increased performance in recreational activities, improved motor skills increase enjoyment and interest in recreation/leisure experiences.

APPLICATION OF TECHNOLOGY

In terms of intervening with individuals with disabilities, life balance must be considered; it must be either established or reestablished (eg. after injury) in one's life. Although during the rehabilitation process in which consideration is given to the mental, physical, social, and psychological/spiritual needs of disable individuals and skills for work and ADL are emphasized, often neglected, or underemphasized, is recreation (1). Opportunity for recreation participation is vital to one's balance and the application of technology for recreation becomes an important aspect in achieving and maintaining life balance.

Many questions should be asked in the application of technology to recreational pursuits of individuals with disabilities. These may include the following:

1. What?

   What activity is to be performed? What is its purpose/goal? Is the activity integrated vs segregated? active or passive? Performed independently or with assistance? Competitive or non competitive? Individual or group activity? Does the activity involve use of equipment? What type of equipment modification will allow for maximum participation?

2. Who?

   Who is the participant and what are his or her needs, abilities, desires, etc.? What is the extent of the individual's impairment? Physical impairment? Sensory impairment? What modifications are appropriate for the individual? Is age a factor? What is the functional ability (physiological, psychological, mechanical)? With whom will the individual participate?

3. When?

   When is it appropriate to apply technology? When does the individual desire assistance? For how long? For technical challenge or to meet the unique technological needs of individual with disabilities?

4. Where?

   In what setting does the individual desire technical assistance? What will be the environmental conditions (weather, surface, sound, etc.)? What will be the environmental effect upon durability, portability? Where will the activity be performed? Institutional setting community setting? Independently or dependently?

5. How?

   How will the technology be applied? Under what conditions can and will learning take place? How will the individual learn to use technology? How will information be communicated/transferred? Can the technology be applied to work and activities of daily living (ADL) as well as recreation?

6. Why?

   Why is technology needed? Could the situation be adapted otherwise? For what purpose? How will the individual interact with the environment? Will the application of technology promote independence or dependence? Does the individual desire technical assistance?

Suggestions for applying technology

1. Encourage and plan for recreation pursuits not just for work and ADL. Interface recreation with vocation and ADL when applying technology.
2. Involve individual with disability in the process of determining the needs for and factors to be considered in applying technology. Avoid imposition of limits on individuals with disabilities.
3. As appropriate, utilize the expertise of others, assemble the necessary resources to complete the task, utilize a team approach to problem solving.
4. Draw upon existing knowledge and understand, avoid "reinventing the wheel".
5. Consider all aspects of recreation and leisure experiences for application of technology (activity itself, instruction/learning, environment, interaction of individual in environment).
6. Give consideration to dissemination of information about recreation and leisure experiences for individuals with disabilities.

SUMMARY

It is important that individuals with disabilities be afforded the same opportunities for recreation and leisure experiences as able bodied individuals. The benefits of participation are many; one's quality of life can be improved. Inasmuch as the applications of technology to creating and enhancing recreational pursuits are limited only by one's creativity and ingenuity, technology can play an important role in fostering participation by individuals with disabilities in recreation and leisure activities.

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(2) DePauw, K.P. (1988). Sport for Individuals with Disabilities: Research Opportunities. Adapted Physical Activity Quarterly. 5 (2).

(3) Peterson, C. & Gunn, S. (1984). Therapeutic Recreation Program Design: Principles and Procedures. Englewood Cliffs, NJ: Prentice Hall.

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THEME SESSION/ SESSION THÉMATIQUE W

Work

Travail

L'ÉVOLUTION ET COMPARAISON DU CADRE LÉGAL AU QUÉBEC CONCERNANT LE TRAVAILLEUR ACCIDENTÉ.

Bernard Cliche
Commission de la santé et de la sécurité du travail

A la fin des années 1970 et au début des années 1980, le gouvernement mit de l'avant un projet de réforme globale de tout le champ de la santé et de la sécurité au travail et de celui de la réparation des lésions professionnelles. La réforme proposée visait deux objectifs majeurs: 1- éliminer à la source les dangers pour la santé, la sécurité et l'intégrité physique des travailleurs, et 2- non seulement compenser financièrement les pertes subies par le travailleur victime d'un accident, mais tenter, dans la mesure du possible, de le réadapter pleinement.

De façon à atteindre le premier objectif, le législateur adoptait en 1979, après de longs débats, la Loi sur la santé et la sécurité du travail (L.R.Q., c. S-2.1). Cette loi regroupait notamment toute une série de dispositions législatives et réglementaires relatives à la santé et à la sécurité au travail, et confiait à un nouvel organisme, la Commission de la santé et de la sécurité du travail, la tâche d'administrer la loi.

Afin d'atteindre son second objectif, qui était de réadapter pleinement le travailleur victime d'un accident ou d'une maladie professionnelle, le législateur adoptait en 1985 une nouvelle Loi sur les accidents du travail et les maladies professionnelles qui réformait de fond en comble tout le domaine de la réparation des lésions professionnelles. Nous croyons utile d'établir brièvement le cheminement législatif ayant mené à cette nouvelle loi.

HISTORIQUE LÉGISLATIF:

La période antérieure à 1909:

Avant 1909, il n'existait au Québec aucun régime juridique particulier concernant les accidents du travail, de sorte que seul le régime de droit commun trouvait application. En vertu de ce régime de droit, le travailleur, pour obtenir réparation, devait poursuivre son patron ou l'un de ses préposés devant les tribunaux judiciaires, prouver la faute délictuelle de ceux-ci pour ensuite être indemnisé en conséquence.

Ce système de la faute délictuelle présentait de sérieux inconvénients tant pour le travailleur que pour le patron. Le travailleur éprouvait fréquemment de sérieuses difficultés à établir la faute du patron, son recours était parfois illusoire ou inexistant à cause du cas fortuit et, dans de nombreux cas, ses ressources financières ne lui permettaient pas de s'engager dans de couteuses procédures judiciaires. En outre, la crainte de représailles pour lui et sa famille le faisait souvent renoncer à ses droits.

Quant au patron, de son côté, il se plaignait de devoir être tenu responsable de la moindre erreur de ses employés, de faire face à des réclamations exagérées et d'être parfois condamné à rembourser des sommes d'argent trop élevées pour ses moyens financiers.

La période postérieure à 1909:

Comme on vient de le voir, le régime juridique de la responsabilité civile basée sur la faute était insatisfaisant pour tout le monde parce qu'inadapté au contexte social et économique de l'époque où le développement industriel créait des risques additionnels pour les travailleurs.

C'est pourquoi le gouvernement de

l'époque adoptait en 1909 la première Loi des accidents du travail (9 Ed. VII, c. 66; S.R.Q. 1925, c. 274) qui reproduisait substantiellement la loi française de 1898, elle-même inspirée des législations existant dans d'autres pays, notamment l'Allemagne (1884), l'Autriche (1887) et l'Angleterre (1897).

Appuyée sur la notion du risque professionnel, cette législation introduisait un système de responsabilité patronale individuelle avec administration judiciaire. Les accidents survenus dans les industries assujetties donnaient droit à une indemnité à la victime ou à ses dépendants et ce, indépendamment de la faute du patron. L'ouvrier ou ses représentants n'avaient plus, en effet, qu'à prouver le fait et les circonstances de l'accident au travail pour avoir droit aux indemnités prévues dans la loi.

D'autre part, cette loi de 1909 limitait le risque professionnel aux accidents survenus par le fait ou à l'occasion du travail dans certaines industries, la maladie professionnelle ne faisant alors pas partie du champ d'application visé. Cette loi de 1909 demeura en vigueur jusqu'en 1928. Entre-temps, elle subit certaines modifications dont, entre autres, celle interdisant à tout patron de faire quelque retenue que ce soit sur le salaire de ses employés aux fins d'assurance contre les accidents ou les maladies survenues par le fait ou à l'occasion du travail.

La période postérieure à 1928:

En 1928, suivant les recommandations d'une Commission d'étude sur le sujet, le législateur québécois adoptait une nouvelle Loi des accidents du travail (18 Geo. V, c. 79) et créait la Commission des accidents du travail qui deviendra par la suite la Commission de la santé et de la sécurité du travail (Loi sur la commission des accidents du travail, 18 Geo. V, c. 80).

En plus de protéger un plus grand nombre d'ouvriers et d'augmenter les indemnités visées, la loi de 1928 imposait aux employeurs l'obligation de souscrire auprès d'une compagnie d'assurance approuvée une police garantissant l'exécution de leurs obligations.

D'autre part, la Commission des accidents du travail se voyait reconnaître un "pouvoir de surveillance, de contrôle et de direction sur les établissements soumis à la Loi des accidents du travail, en vue de la prévention des accidents", accordant également à la Commission l'autorité "de prescrire aux propriétaires et employeurs les mesures de précaution qu'elle juge à propos ... (a. 13)."

En outre, la loi de cette époque faisait obligation à la Commission "de promouvoir la réhabilitation des ouvriers victimes d'accidents du travail et de prendre les mesures qu'elle juge propres pour aider à leur rétablissement dans l'industrie de cette province" (a. 14). Il s'agit-là des premières dispositions législatives concernant la réadaptation.

La période postérieure à 1931:

La Loi des accidents du travail de 1928 ne satisfaisait pas tout le monde puisque les syndicats ouvriers revendiquèrent pour le Québec une loi semblable à celle de la province voisine, l'Ontario, qui jouissait déjà d'un système de compensation basé sur les riques professionnels où les indemnités étaient payées à même un fonds d'assurance collective financé par l'ensemble des employeurs.

Sanctionnée le 4 avril 1931, la Loi des accidents du travail (21 Geo. V, c. 100) reproduisait à toute fin pratique la loi ontarienne et entrait en vigueur le 1er septembre 1931.

Cette loi instaurait le principe de la responsabilité collective des employeurs sur la base de la notion de risque professionnel. Elle créait un fonds d'accident constitué des cotisations exclusives des employeurs devant servir à payer les indemnités, les frais d'administration et les déboursés ayant trait à l'application de la loi.

Il convient de souligner que la loi de 1931 étendait aussi, pour la première fois, le risque professionnel à la maladie industrielle. Ainsi, un certain nombre de ces maladies étaient expressément reconnues à la loi. L'ouvrier atteint d'une telle maladie ou ses dépendants, en cas de décès consécutif à celle-ci, avaient droit aux indemnités prévues par la loi comme s'il s'agissait d'un accident de travail (a. 105.1).

En outre, la Commission des accidents du travail conservait ses pouvoirs en matière de réhabilitation (a. 51), d'inspection (a. 87) et, pour la première fois, il était question d'associations de prévention constituées d'employeurs et possédant d'importants pouvoirs de réglementation en matière de prévention des accidents du travail.

En contrepartie du fait qu'ils finançaient le régime, les employeurs bénéficiaient notamment de l'exemption de poursuites en responsabilité civile et de la prise en charge de la réparation et de la réadaptation par la Commission des accidents du travail.

A l'exception de certains amendements dont les principaux concerneront les indemnités et les procédures d'appel, la loi de 1931 demeurera à toute fin pratique la même jusqu'à l'adoption, en 1985, de la *Loi sur les accidents du travail et les maladies professionnelles* (L.R.Q. c. A-3.1). Soulignons cependant qu'en 1978 la *Loi des accidents du travail* était modifiée pour accroître substantiellement les pouvoirs de la Commission des accidents du travail en matière de réadaptation.

Dorénavant, la loi prévoit que la Commission "prend les mesures qu'elle croit nécessaires et fait les dépenses qu'elle croit opportunes pour contribuer à la réadaptation d'un travailleur victime d'un accident ou d'une maladie professionnelle, pour atténuer ou faire disparaître toute incapacité résultant d'une lésion et pour faciliter son retour à la vie normale et sa réinsertion dans la société et sur le marché du travail."

La période postérieure au 19 août 1985:

Voulant compléter la réforme initiée par la *Loi sur la santé et la sécurité du travail* en 1979, le législateur adoptait, le 23 mai 1985, la *Loi sur les accidents du travail et les maladies professionnelles*. Sanctionnée le 28 mai 1985 et entrée en vigueur le 19 août 1985, elle instaure un régime entièrement nouveau de réparation des lésions professionnelles pour remplacer celui prévu par la *Loi sur les accidents du travail*.

Au chapitre des indemnités, cette loi remplace celles prévues à la *Loi sur les accidents du travail* par une indemnité de remplacement du revenu, équivalant à 90% du revenu net retenu que le travailleur tire annuellement de son emploi, en outre d'une indemnité forfaitaire pour les dommages corporels. De même, en cas de décès du travailleur, le conjoint se voit allouer un montant forfaitaire avec en plus une rente mensuelle pouvant être versée pendant 1, 2 ou 3 ans, selon son âge. Les enfants mineurs reçoivent une rente mensuelle de 250 $ par mois jusqu'à leur majorité et un montant forfaitaire de 9 000 $ est accordé aux enfants majeurs, s'ils sont étudiants. Les autres personnes à la charge du travailleur reçoivent un montant forfaitaire.

Il importe de souligner que la nouvelle loi fait une part très importante au rôle que doivent jouer les professionnels de la santé et, en particulier, le médecin qui a charge du travailleur, y compris le cas échéant, son médecin de famille.

Ainsi, à moins de contestation de l'employeur ou de la Commission de la santé et de la sécurité du travail, c'est le médecin qui a charge du travailleur qui décidera, seul ou avec l'aide de médecins spécialistes, du diagnostic, du degré d'atteinte à l'intégrité physique ou psychique, de l'existence et de l'évaluation des limitations fonctionnelles du travailleur. En outre, ce médecin contribuera à déterminer la nature, la nécessité, la suffisance ou la durée des soins ou des traitements administrés ou prescrits, y compris, bien sûr, les mesures de réadaptation appropriées.

La loi sur les accidents du travail et les maladies professionnelles crée de nouveaux droits en faveur du travailleur, dont certains nous apparaissent d'une grande importance:
- le droit de retour au travail: le travailleur victime d'une lésion professionnelle qui redevient capable d'exercer son emploi a le droit de réintégrer prioritairement son emploi dans l'établissement où il travaillait lorsque s'est manifestée sa lésion ou de réintégrer un emploi équivalent dans cet établissement ou dans un autre établissement de l'employeur.
- le droit à la réadaptation: le travailleur qui subit une atteinte à son intégrité physique ou psychique a droit à la réadaptation que requiert son état en vue de sa réinsertion sociale et professionnelle. A cette fin, la Commission de la santé et de la sécurité du travail prépare et met en oeuvre, avec la collaboration du travailleur un plan individualisé de réadaptation qui peut être modifié s'il survient de nouvelles circonstances.

De façon plus particulière, trois types de réadaptation sont instaurées: la réadaptation physique, la réadaptation sociale et la réadaptation professionnelle.
- la réadaptation physique: la réadaptation physique a pour but d'éliminer ou d'atténuer l'incapacité physique du travailleur et de lui permettre de développer ses capacités résiduelles afin de pallier les limitations fonctionnelles qui résultent de sa lésion professionnelle. Un programme de réadaptation physique peut comprendre notamment des soins médicaux et infirmiers, de traitements de physiothérapie et d'ergothérapie, des exercices d'adaptation à une prothèse ou à une orthèse de même que tout autre soin et traitement jugés nécessaires par le médecin qui a charge du travailleur. En outre, sur prescription de ce médecin, le programme peut comprendre les soins à domicile donnés par un infirmier, un garde-malade auxiliaire ou un aide-malade.
- la réadaptation sociale: ce type de réadaptation vise à aider le travailleur à surmonter les conséquences personnelles et sociales de sa lésion professionnelle, à s'adapter à sa nouvelle situation et à devenir autonome dans sa vie quotidienne. Le contenu d'un programme de réadaptation sociale n'est pas limité, et en plus de comprendre des services professionnels d'intervention psychosociale, il peut prévoir l'adaptation du domicile du travailleur, le paiement de frais d'aide personnelle à domicile, de garde d'enfants et le remboursement du coût des travaux d'entretien du domicile. En outre, la loi prévoit que le véhicule principal du travailleur peut également faire l'objet d'une adaptation en cas d'atteinte permanente grave, dans le but de lui permettre de le conduire lui-même ou d'y avoir accès.
- la réadaptation professionnelle: celle-ci a pour but de faciliter la réintégration du travailleur dans son emploi, dans un emploi équivalent ou, si ce but ne peut être atteint, l'accès à un emploi convenable. Comme dans le cas des autres programmes de réadaptation, la loi n'est pas limitative en ce qui a trait aux divers programmes possibles.

La réadaptation professionnelle peut donc prendre diverses formes. C'est ainsi qu'elle peut comprendre un programme de recyclage ou de formation professionnelle, des services d'évaluation, des possibilités professionnelles et des supports en recherche en emploi, des subventions d'aide à l'embauche pour les employeurs, le remboursement des frais d'adaptation d'un poste de travail, le paiement de frais de recherche d'emploi ou de déménagement et des subventions d'aide à la création d'une entreprise.

Il convient de souligner, en terminant, l'importance que la CSST accorde à la réadaptation de façon à favoriser le retour au travail du plus grand nombre possible d'accidentés, le plus rapidement possible, afin d'amoindrir les difficultés importantes que comporte nécessairement, à tout niveau, une longue absence du travail.

REHABILITATION AFTER PROFESSIONAL INJURY: PROCEDURE FOR PLURIDISCIPLINARY COMMUNICATION

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INTRODUCTION

In 1985, the Province of Quebec passed a new law (Bill 42) updating the previous law regulating work accidents and professional illnesses(4). Among its many changes, it considerably extended the rights and procedures to full rehabilitation following an accident having permanent consequences. These rights include not only direct professional rehabilitation but also the psycho-social aspects of rehabilitation in a broad sense, since the latter represent pre-conditions to a successful and lasting intervention. Other important articles provide the worker with protection of his former job, i.e., the right to return to work which lasts one year in companies of less than 20 employees and two years in larger ones.

This comprehensive legislation has increased not only the number of individuals but also the complexity of the cases since a number of means can now be called upon. The information necessary to evaluate and reach a sensible decision is not limited by the knowledge and experience of a few practitioners. It is now a right of the worker to an extended procedure requiring the combined effort of many professional experts(3).

RESULTS

The sequence of professional interventions

The medical aspect

The procedure begins early, if possible even before the injury is completely healed. The physician assesses the functional limitations resulting from the nature and extent of the impairment and the nature and degree of permanent disability. This assessment is not restricted to the requirements for the professional activities only, but extends to any requirements for an autonomous life. Included also in this evaluation are all activities that should necessarily be restricted to prevent any relapse or worsening of a unstable or precarious physical condition. This combined evaluation of disability and preventive restrictions is a professional medical act. Its exact understanding by a non-medical professional is not always certain, because medical concepts and wording are highly formal and specialized. Extensive explanations may be necessary to convey the right message with the right content.

Conversely, the assessment performed by the physician is made in the clinic or the medical office away from the worksite, and takes into account only sketchy and partial information of the real constraints of the task and working environment. Even if the counsellor in rehabilitation has a practical knowledge of the working conditions, he has to combine these pieces of information into a coherent picture.

At this stage one can pinpoint a gap in the transmission of information due to the division of labor. The same person does not have the specialized knowledge regarding the impairment and the disability in general as well as the specialized knowledge about the constraints of a task and the working environment.

To provide a mean of communication, a tool has been devised in the form of a scale of restrictions. It is to be completed by the physician for the use of the counsellor in rehabilitation . Four forms are provided: 1) the lumbar spine, 2) the cervical spine, 3) the lower limbs and 4) the upper limbs, depending on the location of the disability. The functional restrictions, which include functional limitations already present, are ordered in 5 ascending categories from "no restrictions" to "very severe restrictions". The main feature of the scale consists in expressing the restrictions in action verbs pertinent to each body segment (pulling, lifting, carrying, pushing, crawling, climbing, etc.). These are the commonly action verbs used to describe and classify professions and occupations(1). They therefore represent a common vehicle for communication between the physician and the counsellor in rehabilitation, because both know the generic meaning of these words.

The first benefit of these scales, still under evaluation, seems twofold. First, it eliminates the need for scholarly medical expression. It may look like an apparent loss of scientific rigor; however, these expressions were, more often than not, a source of uncertainty on the part of the non-medical professional who tried to understand them. The second benefit consists in carrying the message of the physician away from a purely medical reference system halfway into an occupational setting. The restrictions may be thus somewhat cruder, but they will not be misunderstood.

The ergonomic aspect

The next phase consists in evaluating the restrictions expressed in generic terms in the working environment, that is in context. To reach that goal a second tool has been developed to guide the counsellor in rehabilitation through this ergonomic phase. The "grid of ergonomic analysis of working conditions" is organized in such a way as to proceed systematically from the general to the particular. It starts with information about the type of economic activity, the size of the corporation, the number of workers, etc., - all data that can be collected by phone. Then, by interview, more will be learned about human resources, work organization, etc., leading to a site visit during which the task, the workstation, the operational mode, the physical and ambient conditions, and the risk and preventive measures can be observed. Finally, the analysis will focus on the actions that were specifically cited as restrictions in the medical report. These actions will be qualified and quantified in relation to the posture, movements, objects handled, pace, duration, frequency, height, amplitude, distance and special skills requirements.

The corrective intervention

A final phase to the procedure was developed to standardize and formalize the search for an optimal solution by mobilizing all available resources.

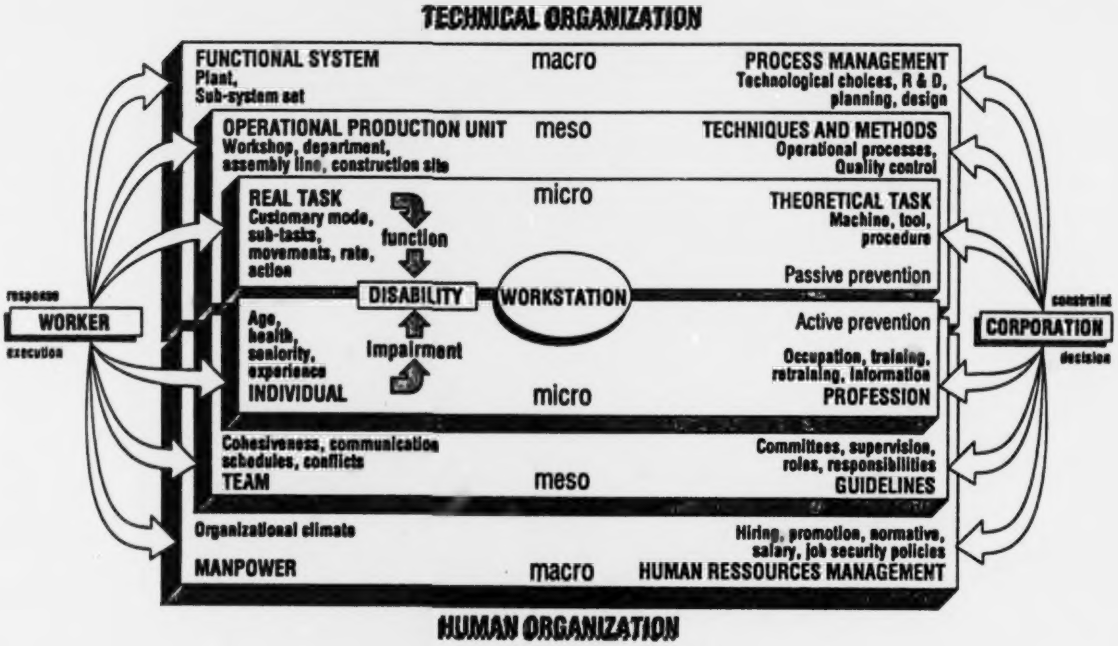
This procedure is a protocol of intervention that includes five steps: 1) Problem definition, 2) Generation of solutions, 3) Analysis and selection, 4) Implementation, 5) Follow-up. This is a very classical problem-solving process.

The procedure developed is based on two main factors: 1) reliance on the knowledge and competence of the resources present in the corporation itself, and 2) reliance on the imaginative creativity of a brainstorming session. The employees of a corporation, be they practitioners or professionals, are the people who know best the applied and formal realities of their working environment. One can be assured that a solution devised within the plant will definitely take the real context into account. Without excluding the possibility of external consultants, the procedure is built around the internal resources first. Regarding the "brainstorming" session, the assumption is based on the fact that partial solutions brought up by participants at all levels in the corporation will cross-fertilize each other. The various aspects of an intervention (technical, operational, organizational, educational...) will be generated by each participant depending on his or her knowledge and vision of the company.

The diagram of the technical and human organization of a corporation

The first part is the graphic representation of the organization of a corporation.

This diagram(2)is centered around the work-station. This is the subject of the meeting because there is a problem between the requirements of this workstation and the worker's incomplete response due to disability.


TECHNICAL ORGANIZATION
FUNCTIONAL SYSTEM
Plant,
Sub-system set
macro
PROCESS MANAGEMENT
Technological choices, R & D,
planning, design
OPERATIONAL PRODUCTION UNIT
Workshop, department,
assembly line, construction site
meso
TECHNIQUES AND METHODS
Operational processes,
Quality control
REAL TASK
Customary mode,
sub-tasks,
movements, rate,
action
function
micro
THEORETICAL TASK
Machine, tool,
procedure
Passive prevention
response
WORKER
execution
DISABILITY
WORKSTATION
constraint
CORPORATION
decision
Age,
health,
seniority,
experience
INDIVIDUAL
impairment
micro
Active prevention
Occupation, training,
retraining, information
PROFESSION
Cohesiveness, communication
schedules, conflicts
TEAM
meso
Committees, supervision,
roles, responsibilities
GUIDELINES
Organizational climate
MANPOWER
macro
Hiring, promotion, normative,
salary, job security policies
HUMAN RESSOURCES MANAGEMENT
HUMAN ORGANIZATION

Overall, this system is the interaction of two poles: worker and corporate poles. Both communicate by means of two channels: human and technical resources.

There are four concepts closely related to the worksite (micro level): 1) the individual (suffering from a precise impairment), 2) the real task (requiring a precise functional level of competence, be it physical or professional). These notions are worker-related. However, the corporation has implemented 3) a theoretical task, that includes machines, tools, procedures that are intended to produce an output. Finally, the corporation employs, and pays for, 4) certain professional skills to execute this task.

At a higher level (meso level), one can consider the individual as part of a team, the real task as part of an operational production unit (the shop, the production line). Similarly, the theoretical task is designed by the department of methods and techniques, and lastly the profession is part of a set of guidelines originating from the direction of the human resources. At the highest level (macro level), the individual is an element of the workforce, the manpower. The real task is part of the functional system. The theoretical task is determined by the process management. The profession is a subset of all the human resources of the corporation.

It is very unusual for a company to revise its general policies and procedures at a macro level to accomodate a single worker; however, it is certain that a problem exists between the individual (with his impairment) and the expected performance of the real task. This is what creates the disability with respect to the work site. Thus, a solution should be found at the "micro" level, even if the original causes are at a higher level or on the corporate side.

The reason for brainstorming then becomes apparent if one realizes that most companies contain personnel with specific zones of competence (and their corresponding role-game).

The foreman is responsible for the worksite, the engineer for the theoretical task, and the supervisor for connecting methods, and techniques on the corporate side with the operational production unit on the workers' side. The union is more or less the mirror image of human resources management. The committee for health and safety as well as the medical and hygiene professionals represent an additional link between both poles.

The solution can originate at any level (macro, meso, micro); it must however involve the individual, the real task and the worksite to be successful.

The last tool is nothing more than a list of questions systematically addressing each concept starting at the "micro" level with the individual. Each concept will then be considered and by the same token, each professional's contribution will be related to his role within the organizational structure.

If more than one solution is generated, a comparison might be necessary. The next step is a stepwise collection of 11 formal criteria (the twelfth being open) to help in an "objective" choice, and if not, at least a ranking of the options.

This entire procedure seems complex. It is not simple but straightforward. The more complicated a problem is, the more helpful the procedure should be. It is especially useful in severe cases, with complex or multiple disabilities.

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WORKPLACE DESIGN: AN ELEMENTAL RESOURCE APPROACH TO TASK ANALYSIS AND HUMAN PERFORMANCE MEASUREMENTS

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INTRODUCTION

The goal in workplace design (or in almost any rehabilitation related endeavor) can be generalized to the basic situation in which a human attempts to accomplish a task. Typically, qualifiers are added so that tasks should be accomplished safely (so as to prevent injury) and as easily as possible. Considerable progress has been made largely via methods which may be characterized as heuristic, difficult to teach (and learn), costly, partially effective, and inefficient. Much attention and funding has been focused on solving problems in each of a host of seemingly different application areas (worker's compensation, environmental design, workplace design, assistive device selection, vocational evaluation, etc). The tendency is to attack these issues with a top-down approach, which is probably good in itself. However, the desire to solve a major problem in a given area over a limited amount of time has led to a series of starts at the top that do not get down to a level where the basic and generalizable situation (i.e. a human accomplishing a task) can be recognized as the root problem requiring study and solution.

The objectives of this presentation are to: (1) generate focused attention to the human-task interface as a common denominator at the "bottom" of many current problems in rehabilitation; (2) suggest an elemental resource model as a basis for systematic approaches; (3) describe the key tools required to implement methods in workplace applications; and (4) generate interest in long-range planning toward improved and more powerful general purpose assessment tools.

BACKGROUND

Many important issues giving rise to the views presented have been summarized elsewhere [1]. Two points are especially significant. The first involves relationships between structure, function, and performance (the latter of which describes how well a given function is executed). The second pertains to selection of the most appropriate level within the hierarchy of the human system for performance measurements. Both issues have weighed most heavily in stimulating the elemental resource model [2-5] summarized below. The model was developed to help understand the interface of the human system to tasks. While details, validations, and applications continue to evolve, the model has been used to explain the assistive device prescription process [3, 6,7], to help define measures of human performance [8,9], and is being used to study high level tasks such as speech [9] and gait [10]. It has also been proposed as a conceptual basis for driver assessment [12] . Interested readers are directed to these sources for references to relevant background works.

ELEMENTAL RESOURCE MODEL

The elemental resource model uses concepts of dimensioned resources and basic elements of performance (BEPs) and, with unavoidable suspension of caveats each deserving special attention, can be summarized as follows:

- In a top-down fashion, the human system is divided into individual structures arranged hierarchically so that each is identified as serving a single function (e.g. elbow flexor: structure; elbow flexion: function).
- Functional units are grouped into three domains (environmental interface, central processing, and life-sustaining).
- Each functional unit is a system itself that can be characterized by a multidimensional performance space.
- Performance is a broad term, defining how well a unit can execute a function (e.g. how fast, how long, etc.). Performance is viewed in terms of resources available (e.g. speed, endurance, etc.) along each dimension of performance that defines the functional unit's performance space.
- A basic element of performance (BEP) is defined by specifying a functional unit and one of its dimensions of performance (e.g. elbow flexor speed, visual memory capacity, etc).
- The collective set of BEPs, representing the respective amounts of resources available along each dimension of performance - combined across all human functional units, forms a performance resource pool.
- To accomplish any task (physical, mental, or combination), humans draw upon BEPs of the appropriate dimension from the pool in the amounts required by the task.
- Successful performance in a specified task is determined by the availability of required resources.
- Determination of which factors are "most important" depends on the integrity of various system components (amount of resources available) relative to task demands.

Basic principles are straightforward. However, the great number of human subsystems and multiple dimensions of performance associated with each results in considerable complexity. Note that a resource-limited situation (the amount of resource available is less than the amount required by a precisely defined task) can result if any one of the required BEPs is stressed beyond availability by the task.

WORKPLACE APPLICATION

Application Requirements: Ideal and Practical

A systematic approach applicable to workplace situations is suggested. Full implementation requires the availability of key tools and components. These include: (1) detailed task analyses in terms that permit assessment against measures of human elemental performance resources; (2) means by which to measure the broad array of an individual's performance resources; and (3) computer simulation models.

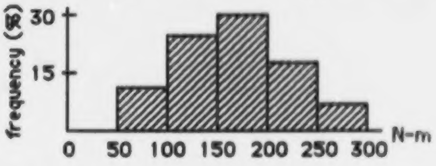
At first glance, this ideal list appears to be awesomely foreboding (the bad news). However, careful consideration reveals encouragement. One recognizes that components of this generalized model are commonly used now in targeted areas. For example, to obtain or renew a driver's license an individual must meet certain minimum vision requirements. Usually, only limited aspects of visual performance are considered (visual acuity, depth perception). It is implied that the amount of these performance resources available must be greater than the worst case demands generated by driving in order for the task to be accomplished. Clearly, other performance resources are important in order to drive (grip strength, information processing speed, etc). If not measured and compared to established criteria, it must then be assumed that these resources are available in sufficient amounts. The fact that the exhaustive list of factors is not taken into account in no way detracts from the utility of considering visual performance. It is apparent that as each resource is measured and compared to a quantitative criterion established based on the task, *the probability of finding a limiting resource is increased*. While ideally desirable, it is not essential to account for all resources in this detailed manner in order to realize the benefits of accounting for whatever number is possible or deemed feasible (the good news).

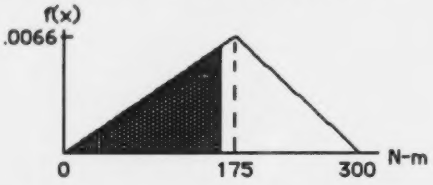
Probabilistic Approach to Assessments

A simple hypothetical example serves to illustrate application. Trunk extension strength is identified as an isolated basic performance resource of interest. As a sample job we choose warehouse laborer. This job is composed of a set of tasks, each of which makes specific demands on trunk extension strength in terms of the amount of torque required. A job analysis identifies 30 different tasks which place demands on trunk extension strength. Biomechanical analyses of each (which can be greatly facilitated with computer simulation models) provide an estimate of the worst-case torque requirement in N-m. during the time-course of each task. We find that the worst case-demand across all 30 tasks is 300 N-m. Furthermore, the frequency of occurrence for each task is estimated. We are concerned with an individual who, upon independent maximal performance testing, exhibits an available trunk extension strength resource of 150 N-m.

One of two different approaches may be pursued depending on one's purpose. By simple comparison of the amount available to the amount required, one can make a global assessment about whether the individual can perform the job (i.e. whether this resource is a limiting factor for any of the 30 tasks). In this example, it can be concluded that the individual cannot perform the job since there are some tasks in which demands exceed availability. The responsible tasks can be identified and removed or redesigned. Note that not all the above information is necessary for an assessment of this type.

Alternately, a different assessment can be performed. Frequency of occurrence and trunk extension torque requirements for each task results in a distribution plot from which a probability density function can be approximated:





Here the distribution plot is generated by summing the relative frequency of each task across all tasks occurring within a given torque range to determine the relative frequency of a specific torque demand on the human system. The shaded area in the probability density function represents the probability that a specific demand will lie between 0 and 150 N-m. This probability is 0.495, and can be interpreted such that an individual with 150 N-m of available trunk extension strength will have a 49.5% chance *of having sufficient trunk extension strength* to accomplish a task randomly selected from those that comprise the job. This method provides a straightforward approach to a meaningful quantitative assessment of an individual in a relatively complex environment. With regard to workplace design, the objective is to maximize this probability. This can be accomplished through iterative redesigns and analyses.

The true complexity of human performance is illustrated by interjection of a second performance resource - for example, hip flexion-extension range of motion. Suppose that similar methods were applied and it was found that the same individual would again show a 49.5% chance of having sufficient hip flex-ext ROM to accomplish a randomly selected task from those that comprise the job. It is recognized that one is really concerned with knowing the probability that the individual has sufficient trunk extension strength and hip flex-ext ROM. This is a joint probability situation and, assuming independence:

$$P(\text{A and B}) = P(A) \times P(B) = 0.495 \times 0.495 = 0.245$$

That is, the individual would only have a 24.5% chance of accomplishing a randomly selected task, assuming all other performance resources are available in sufficient amounts. Further extension of this approach to include additional basic performance resources illustrates that tasks which humans attempt to accomplish represent the interaction of many performance resources. The capacity of an individual with multiple impaired resources compared to a normal reference is related to the product of individual probabilities, each of which is a function of performance measurements. If the probability of sufficiency for any one of the required resources is zero, the overall probability will also be zero. Thus, as a simple check on the validity of the methodology, a blind person would be assessed as being unable to drive despite sufficiency of all other resources other than visual.

BASIC TOOLS

Task Analyses

Most tasks of interest are relatively high level and must be dissected across time to identify more basic components that are then suitable for analysis in terms of the human system's performance resources. For example, lifting involves several phases, each of which makes demands on performance resources of trunk, hip, knee and ankle flexor and extensor subsystems (among others!). Thus, the basic tasks are hip extension, knee flexion, etc. However, tasks can only be analyzed from the task perspective. To analyze a specific lifting task, for example, one can specify the mass of the object, trajectory over which it is to be moved, and speed of movement (or time in which lift must be accomplished). Note that if any parameter is changed, the human must accomplish a different task (perhaps goal is a better term). Computer simulations are required to translate task demands into stresses on the basic human performance resources.

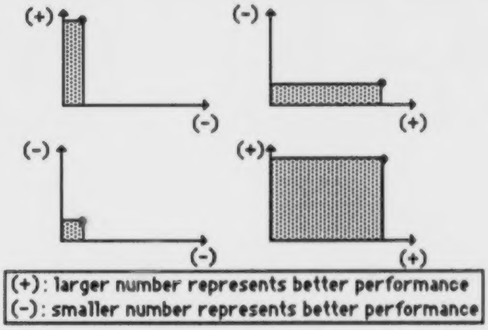
Simple tools such as portable load cells, measuring tapes, and video recorders facilitate task analyses. It is emphasized that the goal is to determine the worst case requirement for each task dimension (XYZ forces, XYZ speeds, etc) during a given phase. Information processing requirements are more difficult to estimate, and further research is required to identify and refine usable methods.

Human Performance Measurements

The elemental resource model provides a basis for defining measures of human performance. Several options are possible, with trade offs between practicality and completeness of description. One option is to design tests to stress a specific functional unit maximally along a specific dimension of performance, in order to determine the amount of performance resource available, i.e., the amount of a given BEP. This type of test, along with the view of performance in terms of resources, implies that performance measurands should be defined such that a larger numerical value indicates better performance. Thus, for example, instead of dealing with reaction time, response speed (the desired resource) emerges as the appropriate measure. This convention provides a basic consistency and facilitates comparison of available resources to those required.

In this author's opinion, the previous lack of a standard convention for measurement definition has contributed more than any other single factor to prevent elucidation of basic principles of human performance measurement and assessment.

This is illustrated by the following plots for two dimensions of a system's performance. Drastically different plots result depending on the convention used to define the measures plotted. Generalizations such as *the amount available must be greater than the amount required* and *functional capacity is proportional to the product of available resources* are impossible to conceive under such circumstances. Confusion is even greater when more than two dimensions must be considered, as is the case in most human subsystems.



Tools are available to measure many of the human performance resources (sensitivities of various sensory systems, strength (ability to produce force or torque), movement speed, range of motion), while others are less common (steadiness, information processing speed, visual short-term memory capacity). Care must be taken to distinguish those tools that provide measures of a single dimension of a high level task (as in gait, lifting or postural stability) from those that isolate the more basic resources (e.g. elbow flexion strength, visual response speed, etc).

Computer Simulation Models

Systems engineering performance models of the human system that integrate biomechanical and other aspects can play a key role in implementing the methods described. There is a one-to-one relationship between certain task requirements and the human performance resource involved (e.g. visual acuity or sensitivity). In other situations, measures of resources available must be mapped into the appropriate task space. For example, performance measures for the shoulder, elbow, wrist, and hand can be used to determine the maximum forces and speeds the hand can impart on an object. Similarly, the inverse problem (given task demands, what are the stresses on each of the basic elements of performance?) can also be addressed with such simulations. Given basic physical task requirements, it is entirely feasible to expect such models to estimate indirect demands on cardiovascular resources as well. Such software represents a powerful and much needed tool to simplify human performance assessments. Unfortunately, few tools of this type are available for general use.

LE GRAND TABLEAU

Workplace design and associated assessments, as well as the many other application areas served by the human-task common denominator, can be facilitated by a general purpose human performance measurement and assessment system envisioned in the future. Largely through the utilization of powerful computer technology, such a system would include:

- databases of performance resources for different normal and pathologic populations to permit use of default values when actual values are unavailable.
- databases and libraries of human system requirements for common tasks (to circumvent the need for repeat analyses), including assistive device operating requirements.
- A combination of subjective and instrumented performance resource measurements, representing intelligent tradeoffs between time and accuracy. Computer prompting users with a checklist of potentially relevant resources will be used to make resource sufficiency assumptions an active process.
- A variety of assessment modes to facilitate (1) task design to match an individual's or population's performance resource profile; (2) determination of functional capacities in broad contexts; (3) objective, quantitative disability determination; (4) computer- assisted assistive device prescription; (5) determination of specific limiting factors and/or safety margins in a selected set of tasks that can be used as a basis for therapeutic planning.

CONCLUDING COMMENTS

Aside from a few twists considered to be important, the methodology described and systems envisioned are analogous to methods commonly used in systems engineering design and to the quite complex systems now commercially available for electronic and mechanical computer-aided engineering. Interest in such tools for human performance engineering applications is emerging not only in rehabilitation involving handicapped individuals, but also in the many industrial and military situations in which a "normal" (or supernormal) human must accomplish a task (fly a fighter plane, etc).

Development of such comprehensive tools represents a task that is too large for any single research group. Rather, a set of such tools developed by many with a common perspective toward integration is more realistic. As described (e.g. for vision in driver assessment), individual pieces of the overall framework can and do stand alone. Due to diveristy of performance profiles of the various disease and injury populations, however, no application area demands more comprehensive and integrated approaches than does rehabilitation. Many of the pieces required to assemble a useable systematic approach now exist and have existed for some time - unfortunately, not in the same place at the same time. Less than comprehensive systems likely to be applied in the interim must be viewed relative to the state-of-the art and not relative to perfection. Such partial approaches can provide significant steps toward reducing error in the current trial and error methods of workplace design, client assessment for vocational purposes, and other similar applications.

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COMPUTER USER ACCEPTABILITY FOR DISABLED PEOPLE

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Computers do represent a promising source of motor, perceptual, and intellectual development for disabled people. They can support all kinds of activities related to learning, work, or recreation, and involving different levels of complexity, from simple reaction or eye-hand coordination to complex human information processing (e.g., orientation, memory, planning, deduction, etc.). More specifically, they can help to develop skills (e.g., typing, tracking moving targets), learn basic matters (e.g., languages, mathematics), perform real tasks (e.g., writing, drawing), ... or simply communicate with other users (e.g., electronic mail).

Furthermore, because they can be interactive, tolerant, adaptable for self-paced activities or the proper level of help to different users, and supportive of a large variety of activities in many domains, computers could represent privileged partners for people depending on continuous and individualized assistance.

As aids to the disabled people, they are likely to play a more and more significant role. This paper reviews some important issues about current realizations and future developments. It is divided into three sections.

1. GIVE ACCESS TO THE COMPUTER

Visiting some rehabilitation centers and briefly reviewing the literature on computers and disabled people led us to realize that tremendous efforts have already been devoted to the basic problem of computer accessibility in relation to individual differences. Let's look at some remarkable examples of adapted I/O (input/output) devices for computer users with physical, sensorial, or mental deficiencies (for a brief list, see [1]).

For users with physical and sensorial deficiencies: easily accessible keypads for turning the computer switch on and off; special hand-, knee-, or foot-controlled keypads for inputs; keyguards for preventing involontary pressing of several keys at a time; keylock mechanism for those who cannot use two or more keys simultaneously (e.g., one-hand operators); software option to turn off auto repeat keys for those with very slow hand motions; myo-electric control of devices such as keyboards or joysticks (in development); miniature keyboard for those with limited arm movements; voice input and output (in development) [2,3]; videodisk systems for those who do not have access to hand-on exercices; expanded keyboards (with large keys, large character inscriptions, colors, and extra space between keys and rows) for those with poor hand controls or the partially sighted users; magnifying glass, enlarged characters on the display, or computer-controlled external screens with large visual feedback, again for the partially sighted users; Braille terminals; artificial vision systems which transmit a TV signal into tactile images on the user's back (in development); etc.

For users with mental deficiencies: restricted keyboards (with less keys); simplified keyboards (with icons on keytops); programmable keyboards (with macros which reduce keying or divide the keyboard into large input sections);

videodisks for concrete, slow, dynamic presentation; etc.

By tackling the key problem of computer accessibility, these developments do satisfy very basic requirements. Still, research and applications in the domain of I/O devices should be pursued so that a larger number of disabled users can be reached, and the quality of the physical and perceptual interaction with the computer can be improved.

It is worth mentioning that these developments must necessarily be based on some analysis of the capabilities, limitations, and preferences of the users. This is actually the starting point of a "user centered system design" philosophy for interactive systems, such as advocated by different human factors specialists [4,5].

2. DESIGN WELL ADAPTED SOFTWARE

Another much challenging issue deals with designing software well adapted to the tasks (activities) to be done with the computer, and the user characteristics. Of course, this preoccupation should normally appear in any interactive system design, but seems much more crucial with disabled users because simple designers' intuition and personal experience are more likely to fail. The goal to be achieved here is clear: develop well-engineered software able to support users who become deeply involved in the tasks and have to perceive, understand, learn, remember what is going on and what can be done in the system.

How should a task be represented into a program? How should it best be supported in terms of computer prompts, error messages, explanation, on-line manuals, icons, input devices, etc.? What will be the *modi operandi* of different disabled users given their specific limitations? There exists no simple model or method to answer these questions. Designers must rely on different sources of information, including task analysis, simulation, ideas from experts in the task domain, evaluation of user difficulties and errors, experimentation (thus testing) all along the design process, etc.

Simultaneously, several user characteristics should be considered for designing more acceptable programs: the users' capabilities and limitations which should permit to set the range of user possibilities; the users' training and experience which should help to choose the proper semantics, terminology, and level of complexity; the users' aspirations which should determine the user interest and motivation in the task; and several other characteristics such as age, sex, language, cultural background, personality, cognitive style, etc. which call for more research and real applications. Several authors have been wishing to see these factors incorporated into the development of computer programs [6,7,8,9].

Here are some examples of simple program adaptations (which deal with the form only): entirely menu-driven applications for minimizing keying; automatic scanning of menus options so as to allow users to simply hit a key (or a keypad) at the proper time; adjustable response time for disabled users with different reaction time; redundant and/or pictorial feedback for better capturing the user's attention or displaying more significant information (e.g., somebody applauding after each good answer); etc.

3. REACH USER ACCEPTABILITY

In agreement with [10], by user acceptability we mean ease of learning, ease of use, and effectiveness in performing the task. This goal is now widely recognized as a fundamental issue of interactive programs. Until relatively recently, too many systems forced users to adapt to the idiosyncratic and cryptic designs of computers, thus provoking widespread uneasiness and malaise among users.

Several interrelated factors directly contribute to user acceptability. The most recognized ones are: compatibility, consistency, transparency, naturalness, simplicity, responsiveness, error tolerance, and explorability. For most of them, there exist some experimental data, principles, or guidelines which already can help designers, but again, further research is needed for a more coherent and integrated understanding of these factors.

Actually, real advances in computer user acceptability for the disabled (as well as able) users will come from different sources: experimental psychological studies for rigorous data on human performance; theoretical works and predictive models of motor, perceptual, cognitive functions [11,12]; computer technology developments which so far gave more powerful computers and more sophisticated user interfaces; basic research and applications in artificial intelligence for natural language processing, voice input and output, vision, robotics, expert systems (e.g., for self-adaptive user interfaces able to accomodate individual users [13]). Several domains such as psychology, linguistics, engineering, physiology, artificial intelligence are involved in this research and development effort.

Finally, we think that progress on computer user acceptability for disabled users is also tributary of a holistic approach. This implies that we go beyond the fundamental but yet too limited considerations for the motor, perceptual, and cognitive aspects, and include affective, social, and organizational aspects as well. There are clear signs in the computer-human factors research community for such a large approach.

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OFFICE AUTOMATION AND THE VISUALLY IMPAIRED:

SOME NEW CAREER OPPORTUNITIES

LEO BISSONNETTE

INTRODUCTION

If you are employed in the 1980's, you are almost inevitably associated with computers in one way or another. Word processors may be used in offices instead of typewriters; payrolls may be computerized; and files, invoices, briefs, reports, and a host of other information may well be on computer disks. Thus, visually impaired people who know something about computers and access technology are today potentially more employable in a wider variety of jobs than they have ever been before.

A snapshot view of office automation, this paper will look at some specific office tasks most suited for the visually impaired as they strive to integrate themselves and their technology into this ever changing work environment.

THE VISUALLY IMPAIRED AND THE OFFICE ENVIRONMENT

General Comments

As we know, computers are becoming more and more important to everyone. And for once it doesn't matter whether--or how well--the person can see the video monitor! The output from a programme being used by a visually impaired person--whether specially designed for their use or an access programme designed to be used with off-the-shelf commercially available software--can usually be read instantaneously on the screen by a sighted person. In fact that output can be produced in paper braille, electronic braille, synthetic speech, large print, regular print--or any combination of the above! This is because all information sent to or received from computers is transmitted in electrical codes which the computer can deal with. The electrical code most commonly used by microcomputers is ASCII (American Standard Code of Information Interchange). The device to which the computer is connected (an electric braille device, a printer, a synthetic speech device, etc.) receives the computer's electrically coded transmission, translates it into the code into which the user wants to see it (braille, print, speech, etc.), and outputs it. Thus, because computers can provide access to such a wide variety of information, they offer visually impaired people an unprecedented degree of independence. And perhaps even more important, because in many cases computers can give both sighted and blind people access to electronic information, without the necessity of modifying that information, computers significantly ease written communication between visually impaired people and sighted people.

Word Processing

Within the past decade or so word processing has become a common task to be performed in the modern office environment. Word processing means that material as small as individual letters and as large as chapters can be inserted, deleted, or moved from one location to another.

Word processing is especially advantageous to visually impaired people. Braille readers in particular are all too familiar with the problems of editing text. How, for instance, do you put a word requiring six spaces where a word requiring three spaces used to be? And if you change the same word more than once, how do you make sense of the jumble of letters and erasures which result? If major changes need to be made in either the brailled or typed versions, an entire page--and quite possible the whole document--may have to be rewritten. The temptation to settle for less polished text which does not have to be so completely rewritten is great!

Word processing significantly reduces such problems. Regardless of how many times you insert, delete, or move material, it never looks as if you have erased! You simply change what needs to be changed and leave the rest of the text intact. When you produce the final version of the document, you get a perfect copy which appears to be your first-time effort!

Today visually impaired persons who perform word processing tasks are using adapted access technologies which contain a number of essential features. First, they contain a command which allows the user to determine the position of the cursor. Thus, the user will always know where the cursor is and can control its movement. Second, the user is able to review the full screen, individual lines, individual words, or individual characters. If individual characters are to be reviewed, all characters--capital letters, lower case letters, punctuation marks, special symbols and control characters--can be identified with the present generation of access technologies available to us.

Automatic Form Writing

One of the most exciting ways in which visually impaired people are taking advantage of the capacities of computers involves automatic form writing. AUTOMATIC FORM WRITING is the process of telling a computer precisely how a particular form is to be filled out, inserting a blank into the printer, and letting the computer put all the information in all the right places. The reason this capacity is so exciting is probably best explained by an example.

Suppose you are a visually impaired office secretary with a number of job-related forms to fill out. Unless you have some way which allows you to read material while it is in the typewriter, you must keep careful notes on how many lines to roll each page in, the line-by-line contents of each form, at what space to begin each response, etc. A co-worker could fill out the forms for you, of course, but that robs you of independence and is an inefficient use of personnel in terms of time and money.

Thus, automatic form writing is a capability especially valuable in the vocational area.

Information Directories and Files

Computerized information directories and files allow visually impaired people to keep a large quantity of information in a small space and to access that information at random relatively easily. The sorting capacity of filing programmes gives these programmes a speed and versatility unavailable using traditional filing methods. This information directory and filing programmes can be a real asset, particularly to the visually impaired professional.

Accounting and Bookkeeping

Many accounting programmes are set up as ELECTRONIC SPREAD SHEETS, blank grids of rows and columns into which information can be entered. Electronic spread sheets allow the user to sum and average these rows and columns in any way the user likes in order to answer the question: "Based on this information, what will column X look like in the future?" The truly exciting thing about electronic spread sheets is that if the user makes one change in the figures, the computer automatically locates all other changes which must be made because of the initial change, calculates the new figures, and inserts these figures in all the right places.

Today's computers and accompanying access technologies make accounting and bookkeeping transactions more independent--and sometimes more private--matters for visually impaired persons to accomplish.

Data Banks

Historically, visually impaired persons have perhaps had less information available to them than has any other group of people. That is why the advent of DATA BANKS, computerized information pools containing entries on a wide variety of topics, is especially important to the visually impaired. Data banks allow users to get the most up-to-the-minute news and stock quotations, research a subject using a computerized encyclopedia, and to do a host of other things--all from their own office workstation and at their convenience.

Data banks are accessed by phone. The user simply connects a modem to his/her computer and phone and dials the data bank's number. (A modem is a small box which transmits signals from the user's computer, to the phone, to the data bank computer and vice versa.) The data bank computer asks the user for their individual account number and password, and once it is confirmed that the information the user gave matches the information it has, the user is admitted.

In an age in which knowing the latest imformation is becoming increasingly important, data banks provide still another way in which the visually impaired can maintain equality with their sighted peers.

CONCLUSION

In this paper we have seen that microcomputers can be used in modern offices to do word processing, automatic form writing, and to prepare information directories and files. We have also discussed how microcomputers can be employed to do accounting and bookkeeping tasks; to access data banks. There is no telling how the future will expand the role of microcomputers in our offices. About all we can say with certainty is that corporations will continue to invest heavily in office automation, and that the microcomputer is such a versatile and powerful tool--that for the present, at least--its potential is limited only by our imagination and common sense.

A VOICE CONTROLLED WORKSTATION FOR HIGH LEVEL QUADRIPLEGICS

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ABSTRACT

The return of some level of independence vocationally and in activities of daily living (ADL) by the quadriplegic person frequently involves the provision of numerous technical aids. Often these aids are electronic devices which facilitate a variety of functions including writing, telephone management and environmental control. Each technical aid has its own input mechanism, or interface, which is fitted to the individual's specific physical capabilities. This paper describes the integration of a number of functions in a voice controlled computer-based workstation and the clinical evaluation of the workstation by spinal cord injured quadriplegic subjects.

INTRODUCTION

In the absense of upper and lower limb motor control, quadriplegics must rely on intact cognitive and verbal ability to direct various aspects of their lives. Technical aids may be provided to augment their remaining physical capabilities. If the technical aid were to have only one function, eg., turning the TV on and off, then this could be accomplished with one switch and one body movement (or interface site). As the operation of the technical aid becomes more complex, the use of a single switch for control requires that the control functions be systematically scanned and then selected for control. This method is time consuming and the individual functions at a slower physical rate than he or she is mentally capable of functioning. This may prevent the individual from being gainfully employed in a competitive market. The work reported on here is a result of efforts to find a more appropriate method of controlling multiple function technical aids for high level quadriplegic persons.

WORKSTATION FEATURES

Telephone Survey

A total of 10 telephone questionnaires were completed to solicit opinions from the target population regarding features they would like to see incorporated into an ideal environmental control system. Specifically, respondents were asked to give their opinions on two different aspects of the system:

i) which functions the system should control (eg:telephone, television, computer, etc),and,

ii) which operating features the system should have (eg: audio and/or visual feedback, remote operation, etc).

The diagnoses of the repondents ranged from C3 incomplete quadriplegia to C6 complete quadriplegia with the following breakdown:

C3	- 1 incomplete	C5	- 1 complete
C4,5	- 3 complete	C5,6	- 2 complete
	- 1 incomplete	C6	- 2 complete

Nine of the ten respondents were using at least one device to operate appliances in their environment. All respondents were able to independently operate their environmental control systems or devices when set up appropriately. Four respondents required assistance to reposition their input switches when they moved from their bed to their wheelchair.

The items in each of these categories were rated from 1 to 5; 1 indicating that it was of little or no importance to them and 5 indicating that it was very important to them. Relative scores were established by multiplying the number of times a rating value was given by the rating value and totalling these for each item. The scores for the functions controlled and the operating features of the ideal environmental control system are listed below in Table 1.

Functions Controlled	**Score**
Emergency Call	49
Telephone	46
Radio - on/off	41
Radio - channel control	41
Ceiling light - on/off	40
Computer - control	38
Door lock	36
Intercom	36
Tape recorder	35
Desk light - on/off	35
Television - on/off	34
Television - channel control	34
Radio - volume control	33
Computer - on/off	33
Operating Features	**Score**
Remote control	42
Simple to operate	42
Multitasking	42
Inexpensive	40
Provides audio feedback	38
Available in component parts	37
Computer based system	36
Provides visual feedback	28

Table 1: Sums of weighted ratings for functions and features of an ideal technical aid elicited from the Telephone Questionnaire.

The high rating of communication functions (eg: emergency call, telephone) indicated the importance of ensuring that the voice recognition system selected for this workstation offered the phone management function.

Voice Recognition Hardware

Commercial voice recognition systems were evaluated (Snell, E. et al, 1987) from Texas Instruments, Votan and Roar Technologies in a PC-XT compatible computer for their suitability in workstation applications. The systems were assessed for recognition accuracy, vocabulary sizes, host system memory requirements, keystroke output capabilities, vocabulary booting capabilities, vocabulary training procedures, vocabulary switching techniques, synthesized and digitized speech response capabilities, availability of telephone manager hardware and general product support. The results indicated that the selection of a voice recognition system is strongly influenced by the particular application for which it is required.

Both Texas Instruments and Votan have optional boards that piggy-back their voice recognition boards to perform telephone management functions. The telephone managers typically can operate as telephone answering machines and can store telephone number lists for later retrieval and automatic dialing. Another feature of the telephone manager allows input to the voice recognition board via a standard telephone handset. An extension of this input method allows standard cordless telephones to be used for remote voice entry. This remote input method must be capable of providing the user with feedback, indicating whether the computer is responding appropriately to the commands given.

The Texas Instruments system was the only telephone manager which allowed total voice control over answering the telephone, dialing telephone numbers and using the speaker and microphone combination as a speakerphone. The telephone manager software ran as a background program and could be superimposed on an application program, such as word processing, to access the telephone functions without exiting the application program. The cordless telephone could not be used for remote access to the workstation when the telephone manager software was activated due to software limitations.

All boards demonstrated good recognition accuracy with the tested standard vocabulary. Accuracy of recognition seem to be quite dependent on microphone positioning. Best performance was obtained when the microphone was placed to one side of the mouth. Repositioning of the microphone from one session to another was critical. The effects of this can be reduced by the use of a telephone handset for input since the mouthpiece is mechanically repositioned by the shape of the handset. As voice recognition was used with a number of programs in a simulated workstation environment, it became apparent that the number of phrases immediately available to the user had a more significant effect on performance than recognition accuracy. Smaller immediate vocabularies resulted in some phrases, especially vocabulary switching phrases, being duplicated a number of times. Additionally the smaller vocabularies required an utterance to select the appropriate vocabulary and a second utterance to obtain the desired keystroke output.

Remote Access

The Realistic Model TRC500 headset walkie-talkies are small voice activated FM (frequency modulation) transceivers that can fit into a shirt pocket and come complete with a headset and boom microphone. The antenna is built into the headband. The cost for a pair of transceivers is approximately $130.00 Cdn. This transceiver was found to be inappropriate for this application due to the limited range and quality of transmission in typical office environments. Different results might have been obtained in an environment such as a wood frame house, which would have less effect on radio signals.

The Texas Instruments voice recognition system allows the user to provide voice input either through the microphone input or through a telephone handset via the telephone manager hardware. A cordless telephone receiver was connected to the telephone input on the telephone manager hardware and the cordless handset was used as the remote input device for voice recognition. Using the telephone as an input device disconnects the telephone lines from the telephone manager and disables all other telephone management functions. This transceiver performed better than the previously tested system, but the range was limited to approximately 10 meters with reduced recognition accuracy and still did not produce acceptable results. The radio link was therefore not used during the clinical evaluation of the complete workstation.

Feedback to the user from the workstation in response to commands given remotely to the workstation is very important. Verbal feedback would be an asset but ideally the user could most benefit from actual computer screen information. Short range video transmitters are commercially available for approximately $70.00 Cdn. that can be connected to the computer video output. The computer screen information can then be received on any portable television set. Electronic noise and radio frequency barriers in an office environment will restrict the range of transmission and the distance the user can be from the workstation.

In order to provide reliable remote control of the workstation further work is required to test industrial grade transmitters that are virtually unaffected by office type enviromental noises. The costs of such systems may be prohibitive and not conducive for integration into the workstation.

Infrared Control

An infrared controller gives remote access to home entertainment devices by transmitting an encoded invisible light signal in the infrared wavelength from the hand-held transmitter to the entertainment device. A General Electric Control Central Infrared Controller was chosen (Shire, B. et al, 1988) as the transmitter to provide the infrared link between the voice recognition work station and the entertainment devices. This is a commercially available hand-held infrared controller, similar to any TV or VCR remote control. In addition to having a number of set infrared commands for General Electric (GE) devices, it also has the ability to learn and repeat the infrared codes of other controllers. This makes it possible to have a single infrared controller to operate all the infrared controlled devices within a house. The use of one controller for all devices also means that only one interface unit must be built.

Hands-free operation of the infrared controller is achieved by the voice controlled workstation and the add-on Interface Unit. The voice recognition system outputs keystrokes to DOS that causes ASCII text files to be copied to the RS-232, COM1, port where the Interface Unit is connected by cable. For each infrared voice command function, there is a separate text file copied to the RS-232 port that the single-chip microcomputer (68705R3), in the Interface Unit, interprets and uses to implement simulated keypad depressions on the Control Central.

Enviromental Control

The Powerhouse controller is commercially available from department stores (approx. $140.00 Cdn.) for the IBM PC, Apple, Commodore 64 or compatible personal computers. The hardware is the same for all computers except for the interconnecting cable, but the software is specific to the computer being used. The Powerhouse can address up to 255 separate modules through combinations of 16 house codes and 16 device codes. The module address codes are transmitted along the existing home electrical wiring and allows the user to switch line operated devices ON, OFF or control lamp intensity through easily connected modules. In the workstation application, all devices could be accessed through the computer using voice commands or keystrokes and did not require any hardware modifications for this to be accomplished.

The software for the Powerhouse allows the user to program ON and OFF days and times, and once these have been set, the Powerhouse performs these functions independently of the computer. A battery backup function is provided to allow the Powerhouse to retain this programmed information in the event of a power failure.

CLINICAL EVALUATION

Training Program

A training program was designed to cover three areas: basic introduction to the use of the microcomputer, voice training and training in the use of the workstation functions. It is recognized that very little computer training can be completed in the three, one-and-a-half hour, training/evaluation sessions and it was expected that subjects would develop only a simple familiarity with the computer to allow them to operate the workstation with minimal prompting. A list of the vocabularies was mounted and displayed in the workstation area for easy reference by the subjects during the training and evaluation sessions. The training and evaluation of this experimental system took place in a hospital setting with limited time for practice and no opportunity for integration into the users' homes and lifestyles. It is felt, however, that very valuable information was obtained during the training sessions through the timed tests and from the subjects' solicited and unsolicited comments.

Background Information

Subject background information was collected in the following areas: sex, age, medical history (diagnosis), functional status, social history, educational status, vocational status, microcomputer experience, familiarity with technical aids, system currently used and avocational interests. This information was collected to be correlated with the subjects' performance in the voice training, their use of the system and their opinion of the system.

Performance Testing

A number of measures of recognition and performance were used. Persons who required less time to train the system received higher word recognition scores in the test. The Pearson correlation coefficients were calculated between recognition scores and training time scores is -0.895. This is significant at the p <0.01 level. None of the background variables correlates significantly with recognition and training scores. This means that the performance on the voice recognition system, as measured by the computer's recognition score, is independent of age, the duration of a person's disability, years of schooling, and years of computer use. This is true for the training time scores as well.

A test was devised by the project's occupational therapist to evaluate a number of integrated functional activities. In this test the subjects had to start, carry out, stop or change an activity with the Voice Controlled Work Station (VCWS). Three distinct functional tests were included; making a telephone call, operating the radio and changing the channel, and carrying out a few wordprocessing operations. These three tasks were performed using the subjects' present systems and also using the VCWS. These activities were timed as were the times taken by each subject for the entire activity.

The means of the ratings that the subjects gave to the technology were calculated. It is clear that degrees of appreciation (1 = highly unfavourable, 5 = highly favourable) have virtually no relationship with background variables nor with the recognition and training scores. A correlation that was of some interest (though not statistically significant) was the 0.661 correlation between the Average User's Rating and the Duration of Disability. Thus persons who had been disabled longer were more likely to respond favourably than persons who were more recently disabled.

CONCLUSIONS

The results of this study indicate that the environmental control systems currently used by high level quadriplegics do not meet all of their identified needs. This has been shown to be true particularly for the C4 and C5 quadriplegics who rely more heavily on technical aids for independent control of devices in their environment. The gaps identified by this population include control of volume or channel selection of entertainment appliances and access to an integrated telephone system which includes an answering machine. Also desired by this population is a single system that will provide telephone functions, environmental control and written communication. The voice controlled workstation was positively received by the study participants because it met many of these identified needs.

From the point of view of a quantitative analysis of the data a number of conclusions can be drawn:

1. Given the minimal training and practice that the subjects received, the performance of each subject was very consistent both across vocabularies and across functional tasks. This is probably due to the good performance of the hardware on the one hand, and to the relative ease with which this technology can be mastered.

2. The high correlations between the computer-based recognition scores and the Integrated Function Test, a test of four functional workstation-related activities, confirms the validity and usefulness of the computer-based scores.

3. Some indirect evidence was found for the statement that this technology is "self-selecting" or "need-seeking". Persons who needed the technology (i.e. persons who already used a component part, such as an environmental control system) performed better on the Integrated Function Test than the two subjects who could perform these functions manually. In this sense the system worked best for the subjects who really needed it.

The results of this study also indicate that the use of voice input was well received by the target population. The elimination of splints and switches decreases the assistance required by the user for application and positioning. The only area in which voice input was felt to be limiting was written communication through word processing. Some subjects felt that spelling out each word would not provide a fast enough method of written communication. This problem could be addressed through the selection of alternative software which allows input of complete words through voice, or through a predictive spelling program working in conjunction with wordprocessing software.

A need that has been identified by the target population and remains unmet at the conclusion of this study is the ability to operate all of the workstation functions, in a closed loop fashion, from anywhere in their room or home. Many subjects indicated that their mobility is decreased because they have to be at their environmental control system which currently must remain in a fixed location. It can be concluded that there is a great need for either remote access to the system or a method of having the system move with the user.

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Copies of the Executive Summary for this project can be obtained by contacting:

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URBAN TRANSIT SYSTEMS: ACCESS AND INTEGRATION

STEVEN C. WILKS

Industry, governments and consumer groups have all embarked on studies to carve out future courses of action to address the transportation requirements of Canada's disabled population.

The Canadian Paraplegic Association (CPA), for example, has embarked on this study of urban transportation systems with a focus on accessibility and integration. It appears that the objectives of the CPA study captures the flavour of the Canadian consumer movement of the 80's. That is, to learn from the experiences in the international scene in general and the United States specifically; to learn from what transpired with the Rehabilitation Act of 1973, Regulation 504; recognize the resistance to the total accessibility concept by both the industry and many consumers; recognize environmental constraints (i.e., Canadian winters) and physical barriers, both of which significantly restrict one's ability to access most goods and services; and realize within any public transit system, there exists a place for a parallel or specialized service which may better complement conventional transit services.

Today, the financial resources for transit are severely limited and the immediate prospect for increasing the level of support for transit is dim despite the well-documented needs that exist. In this fiscal environment, the critical issue has become one of balance -- balance between all public services competing for limited resources, and balance between transit services to the community as a whole and the special, more costly services required by or demanded by different segments of the community.

The high cost of making all transportation accessible is the most frequently voiced concern.

Inclusion of design elements in new construction that insure barrier free environments can incrementally increase costs but in fact, the two most costly transportation solution studies (i.e. retrofitting BART and Washington Metro) were carried out for 1.6% and 1% of total costs respectively.

Another area of concern often raised regarding the costs of accessibility is the question of safety; safety of the disabled person and safety of others travelling with a disabled person. There does however exist a philosophy known to many of us as "prudent risk".

Total safety, especially for the handicapped individual, is not presently possible... It is imperative that the disabled individual be allowed to bear a certain level of risk (personal cost), within reasonable limits, rather than unilaterally exclude him from the systems.

The policy shifts and controversies of recent years illustrate the difficulty of reaching agreement on a single approach to elderly and handicapped transportation. Numerous special services have been tried, many with tremendous success. However, certain problems are persistent.

Coordination between the groups offering elderly and handicapped transportation--which number in the thousands--has already been cited as cumbersome and time-consuming. Budget constraints are impinging on all who operate transportation for the disabled. Ideas that succeed in one location often fail in another because of unanticipated problems with climate, topography, or other site-specific features. These problems, combined with variations in the number and types of disabilities that a single special service must address, argue strongly for local control over the planning and implementation of transportation for the elderly and handicapped.

This report is not intended to be an exhaustive analysis of the types, costs, efficiencies, or practical advantages of special elderly and handicapped service.

However, certain considerations are common to the planning and decisionmaking processes related to special services: accessibility versus mobility; cost-effectiveness and funding; and equipment reliability and availability.

The distinction between accessibility and mobility has characterized much of the political and legal debate over elderly and handicapped transportation. The U.S. "504" regulations mandating fixed-route transit accessibility were premised on the concept of "mainstreaming" the edlerly and handicapped into the transit available to the general public, rather than treating them as a separate group with "special" programs. Unfortunately, accessible buses or trains do not often accommodate the total transportation needs of the disabled; they are but one mode of a trip that for the mobility-impaired individual would require at least two. The concept of overall mobility, i.e. getting from door to door, is therefore only partially addressed by the requirement for accessible transit.

The cost of implementing fixed-route accessible transit that often goes unused because of individual mobility impediments has seemed unacceptable to many in the transit community. Accessible public transit, as an end in itself, addresses only the issue of discrimination in federally funded programs and may prove practical in some communities. Efforts that focus on overall mobility, however, bear more relevance to actual transportation needs. The option of either approach is open to transit operators and the implications of selecting one over the other should be thoroughly addressed.

Costs play a large role in a transit operator's selection of a special services approach. The requirement for fixed-route accessibility brought with it certain fixed costs and in some ways obviated the need for a cost-benefit analysis of different options. The return to a locally-determined "special efforts" approach offers more flexibility in weighing costs and benefits against available funds but requires information and analysis tools that have not been well developed over the past few years.

No approach to elderly and handicapped transportation is inexpensive. Paratransit systems have costs generally lower per boarding than accessible transit, but costs of $10-$15 per trip are common for lift-equipped paratransit.

Clearly, costs must be weighed against other factors, particularly use. Statistics on the use of lift-equipped buses have raised questions about their value. The trade-offs that must be considered are obviously complex and highly unique to each locality. Budget restrictions, particularly on the operating side, will make the choices even harder and the need to seek or generate revenues for these services greater.

The availability and reliability of fixed-route transit equipment that can accommodate the handicapped has lagged far behind the requirements for its use. Lifts for buses are the most well known problem. The experience of transit operators with lift-equipped buses has shown that the equipment is unreliable. Systems complying with the "504" regulations found themselves needing a larger bus fleet and more spare parts in order to accommodate service requirements with operable lift-equipped buses.

The review of alternate transportation scenarios including accessibility features on conventional transit, user-side subsidies in the form of taxi scrip services, paratransit services, etc., suggests that it is not possible to recommend a single transportation solution that is clearly the most cost-effective for all handicapped people in all situations. The cost-effectiveness of any alternative can vary widely, depending on local conditions and many other factors. A solution that may work well in one community can easily fail in another. Most likely, some combinations of alternative solutions will be required, each focusing on particular needs of particular market segments. In short, an integrated fully accessible system; one in which there may be several components designed to be fully accessible to as many people as possible.

Components will vary according to the circumstances of a community but the services will be coordinated and be as equal as possible. Through coordination such as the integrated system previously discussed cost-efficient transportation can be provided to people in a flexible way that allows for the particular and unique circumstances of smaller centres and people with special needs.

The components of an integrated urban transit system or family of services may include any or all of the following:

- a) enhanced accessibility features on conventional transit buses
- b) accessible Rapid Transit (LRT or Heavy rail and commuter)
- c) accessible specialized vehicles (ramp or lift equipped)
- d) agency or institutionally owned and volunteer or staff driven cars and accessible vehicles
- e) private cars/vans
- f) accessible taxis (private sector)

The coordination of these components into an integrated system will become possible as more accessible equipment is acquired over time. As we have learned from the BART system, Vancouver Sky Train, the Washington Metro, Edmonton's LRT, etc., it is possible to build and operate an accessible Rapid Transit System. The technology is available and so is the environmental design, knowledge and ability.

Retrofitting can be phased in over a period of time and all new installations and equipment should incorporate accessibility automatically in the design process. As replacement of equipment is scheduled, equipment to facilitate enhanced accessibility should be acquired. This would apply to commuter rail and bus systems as well.

We know that unless systems begin incorporating accessibility features, the specialized services will have to expand very considerably, incurring both capital and growing operating costs of their own. If systems are integrated and incorporate features to enhance accessibility, there will be cost offsets since the demand for full specialized services will be reduced. One may expect that specialized services will, to a large extent be used as "feeder" lines to main systems, especially where rapid transit is available and accessible. The specialized service would include use of taxis, mini-vans and purposebuilt vehicles that could be used to provide short journeys limited to main transportation services. It would also continue to meet the needs for door-to-door service that some individuals will always require.

In conclusion, what is needed throughout Canada is an integrated transportation network that may have many components, every one of which will be fully accessible to as many people as possible.

GETTING THERE: A MODEL FOR ASSESSING NEEDS AND SOLUTIONS IN TRANSPORTATION FOR DISABLED USERS

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INTRODUCTION

As a society, we are getting there in terms of gradually integrating disabled persons into the workplace. The legislative framework in Ontario, Canada, North America and indeed around the world, is improving disabled persons ability to participate in all of those aspects of daily living which most of us take for granted. Accessible transportation both to and from work, is one crucial aspect that requires further resolution if disabled persons are to live truly independent lives. This paper suggests a model by which needs and solutions in transportation technology for disabled persons can be identified in a systematic framework based on functional limitations.

In March 1987, a report entitled The Freedom to Move is Life Itself, was produced by the Ontario Advisory Councils on Senior Citizens and Disabled Persons.[1] The Freedom to Move report has received wide acclaim, provincially, nationally and internationally. It presents the argument that a community without transportation handicaps its residents and a transportation system which is not accessible or available to all residents, handicaps the community.[2]

In their report, members of the Ontario Advisory Council on Senior Citizens and the Ontario Advisory Council on Disabled Persons advance an increasingly prevalent position, that the absence of transportation facilities and the inaccessibility of existing systems create a handicapping environment and therefore violates the human rights of many citizens.[3]

The vision of the report is based on the principle of universality of opportunity and contends that it is not enough to increase the mobility of some members of society only, since this perpetuates segregation and does nothing to eliminate systemic discrimination.[4]

No matter which country, region or community in which one lives, transportation is the essential link between home, work, medical or religious facilities, shopping centres, volunteer, social and recreational opportunities. Without appropriate accessible transportation, disabled persons are denied the opportunity of being independent. This includes not only the physically disabled, but also the frail elderly and those with other handicapping conditions.

The World Health Organization defines a HANDICAP as a disadvantage for a given individual, resulting from an impairment or a disability that limits or prevents the fulfillment of a role that is normal, depending on age, sex, social and cultural factors. For the individual, a DISABILITY is any restriction or lack of ability to perform an activity in the manner or within the range considered normal for an individual.[5] Instead of utilizing this definition as it applies to individuals alone, it is now time to look at those transportation systems that are inaccessible or inhibit human functioning and which do not allow integration of disabled persons into the mainstream and to work opportunities.

Our purpose therefore is to find ways of creating accessible transportation environments and systems that accommodate both disabled persons and an aging population who are willing and should be able to contribute to and enjoy society's economic, cultural and community future.

It has been estimated that 23%, or almost one quarter of all the residents of Canada have some chronic condition, or functional disability.[6] Functional limitations can be defined as those limitations which affect the way in which individuals use or interact with the environment. For example, those who cannot see, have a functional limitation that prevents them from reading normal directional signs, however they may not have a functional limitation with respect to braille signage. Another example might include seniors who do not have the strength to stand for any length of time while waiting for a bus; their functional limitation is related to "strength and endurance". An easy solution might be to provide a seat at the bus stop.

Based on the initial philosophy that people with functional limitations, ie: generic handicapping conditions, have the same needs and rights to appropriate transportation as the rest of the community, it is imperative that accessible transportation services and systems be developed to serve all persons, regardless of functional limitations.

The demands and use of accessible transportation services and facilities are growing rapidly, especially where such services are available. It has also been identified that where specialized or parallel services are available, a point is frequently reached where potential riders can no longer obtain the necessary services. In addition, eligibility requirements generally limit use to specific trip purposes and individuals, often within specific time frames and booking arrangements.

In order to understand the potential need and demand for accessible transportation services and related facilities, we recommend a systematic methodology to identify user requirements and solution approaches based on generic functional limitations. Such an approach has significant advantages over the historical criteria in which wheelchair users' needs only are utilized as the basis for approaching accessible transportation solutions.

Since the actual numbers of persons who are travel disadvantaged are not generally or systematically documented in a way which allows engineers and systems designers to rationalize solutions, this "functional limitations" approach allows inclusion of the majority of disabled and frail elderly persons in systems analysis and design.

The list of functional limitations which is recommended for this approach is displayed in Figure 1.

FIGURE 1:

Mobility:

Persons with walking problems or requiring a variety of mobility aids.

Sensory:

Persons with sight or hearing loss, and/or including persons with reduced touch sensitivity; inability to smell or taste.

Co-ordination

Persons with spasticity, hand-eye co-ordination problems, arthritic conditions etc.

Strength and Endurance:

Persons with systemic impairments, eg: heart disease, high blood pressure, breathing problems etc.

Comprehension:

Persons with learning or understanding disabilities, including the developmentally handicapped, the learning disabled, those suffering from confusion or memory loss, as a result of a disabling condition or disease, or induced by substance dependency.

Situational:

Persons who, because of size or weight are at a disadvantage, or persons who are culturally (language) or otherwise at a temporary disadvantage in a given situation, eg: pregnancy.

These major functional limitations can be used systematically to identify actual barriers in specific physical or operational situations, as well as in theoretical or research situations. They can also be utilized in the development of solutions and strategies with respect to specific technologies in the field of transportation.

In utilizing an organized approach to dealing with functional limitations, we also find that barriers can be broken down into three major categories, as follows:

FIGURE 2:

Physical Barriers:

Those physical barriers in the built environment which interrupt or inhibit movement or use, such as curbs, steps and narrow doorways.

Systems Barriers:

Those barriers which are specific to particular facilities or operations; including mechanical and electrical systems, as well as other specialized systems, equipment, technological devices, vehicles, plus information systems such as public address, telephones, signage etc.

Service Barriers:

Those barriers which are people-related and include attitudinal barriers, procedures, protocols, legislative and safety requirements, staff training etc.

In order to quantify or evaluate typical barriers in transportation settings, vehicles or equipment, a further systematic approach is required, which assists in determining appropriate solutions, eg: for either an individual traveller or in the case of system-wide design, for any number of disabled or elderly travellers. The approach therefore we generally recommend is a scenario approach. These scenarios can be generated for:

1) Individual trips to and from home to the work place (or other destination) and back, using a specific mode of transportation.

2) Any number of individuals having the same functional limitation in specific settings or on specific routes, using specific modes of transportation.

3) All persons with functional limitations, requiring access to a coherent, integrated, or specific transportation system, or mode.

To date, the majority of research undertaken by rehabilitation engineers has focussed on the type (1) scenario above, ie: for specific individuals and/or for one major group of functional limitations, eg: the mobility-impaired, wheelchair user. While it is true that this category of user has the greatest problems with public transportation systems, nevertheless they represent only a portion of all of those with transportation difficulties.

Recent projects undertaken by Associated Planning Consultants Inc. in Canada include the development of typical broad scenarios, covering the spectrum of functional limitations. These scenarios have been utilized to develop checklists to identify and quantify travel barriers, in particular transportation systems and settings, including rail and bus travel as well as airports.[7] Sample scenarios were developed for the Canadian Human Rights Commission, as a general aid in evaluating train stations and passenger cars. The various Scenarios were co-ordinated with specific performance criteria and checklists for each of the types of barrier identified in Figure 2, capable of being analyzed manually or by computer.[8]

The key barriers to use and integration of disabled travellers could then be identified and checks on the level of incidence recorded in specific settings. This pragmatic approach was also utilized in evaluating the VIA RAIL system in Canada and allowed the client to isolate and remedy the most significant barriers using a cost-benefit approach benefiting the greatest number of disabled travellers.

In the report "Freedom to Move", a number of priorities for research and development and of interest to the Rehabilitation community, were identified by consumers and advocates with respect to transportation. These included:

1) Product related (wheelchairs):

   - Improved chairs for transporting quadraplegics.
   - Development of lighter-weight, less cumbersome wheelchairs.
   - Improvements in size, weight and travel safety features of batteries for mobility aids.

2) System related (cars/transit vehicles):

   - Improved car design to allow ease of entry and egress.
   - An efficient, possibly retractable, lower step for buses.

3) Information related (signage, phone systems etc.)

   - Improved Public Announcement Systems on Transit Vehicles and in terminals to improve accessibility.

- Development of tactile and visual information systems appropriate for visually impaired and hearing impaired persons in transportation facilities.
- Make accessible telephones.

4) Physical environment related (broad/architectural barriers):

- Narrowing of gap between edge of platform and mass transit vehicles (trans etc.) to improve access and egress of small wheeled (ie: electric) wheelchairs.
- Non-slip tile floors in transit stations for mobility aid users (ie: braces, crutches etc.).
- Improved lift and/or ramp technology. (Current equipment is still mechanically inadequate. Operating reliability, maintenance costs and ease of operation are still major problems).
- Improved and more reliable escalators, ideally accessible to mobility aids.
- Emergency exit hardware.[9]

Much has been achieved and is still being done in every western country to remedy barriers in the physical environment, through changes to building codes and the development of design guidelines. However, most of this effort too is directed at wheelchair users, who are perceived to be at the greatest disadvantage in travel situations. Similarly, much of the rehabilitation engineering effort on individual mobility has concentrated on this same group of disabled users.

Although each of the recommendations above are areas for further research and development relative to transportation technology, all disabled users of transportation would benefit from broader, more systematic research, utilizing a functional limitations approach. In particular, in this rapidly changing age of technology transfer, research and related solutions, which to date have focused on individual needs, eg: for wheelchair users, or the blind, might well be redirected to this overall approach to the benefit of the majority of disabled persons interested in joining the work force.

CONCLUSION

As leading professionals in the field of rehabilitation technology, we urge you therefore to systematically analyze and quantify barriers as well as solutions that will improve transportation opportunities for persons with diverse functional limitations. By thus addressing the variety of barriers currently imposed on special users by existing transportation systems, we will go a long way to ensuring the future integration of disabled persons into the mainstream and into the workforce. Only then can we truly say that we are "getting there" and that all members of our society are equal partners in that enterprise.

FOOTNOTES

1. Ontario Advisory Council on Senior Citizens, Ontario Advisory Council on Disabled Persons. The Freedom to Move is Life Itself, Toronto, 1987.
2. Ibid, Page 1.
3. Ibid.
4. Ibid, Page i.
5. Ibid, Page 9.
6. Department of National Health and Welfare, Disabled Persons in Canada, Ottawa, 1980.
7. See, for example A.W. Cluff & P.J. Cluff/Associated Planning Consultants Inc. Physical Accessibility for the Handicapped, Toronto, 1981 and Associated Planning Consultants Inc., Access - Terminal One, Toronto, 1981.
8. Associated Planning Consultants Inc., Consulting Services on Accessibility and Adaptation Planning, Toronto, 1983.
9. Ontario Advisory Council on Senior Citizens, Ontario Advisory Council on Disabled Persons, The Freedom to Move is Life Itself, Toronto, 1987, p. V-XIV.

ACCESS TO WORK

France Verville, coordonnatrice des services de réadaptation et d'emploi
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For 15 years the Quebec Paraplegic Association has been sponsor to an Extension Project (Canada Employment and Immigration) where each year over 100 Physically Disabled Persons are counselled and of whom 90 % find full-time employment in the work force.

In the last ten years, the Project has been witness to the very rapid evolution of technology both in the fields of Rehabilitation and Employment. For the Physically Disabled technology serves in a wide sense: to control one's environment, independantly, to potentially save time and energy and to compensate for physical, sensory and cognitive impairments.

For the Physically Disabled to ACCESS WORK it has been our experience that2technological factors are imperative: Transportation and universal Accessibility to Public Buildings. To adapt work stations for specific needs of a person and for the task at hand, this will be done on an individual basis of evaluation. These adaptations serve to compensate physical disabilities; they are useful to the extent that the person cannot do without them and without loss of productivity. In order to ACCESS WORK, competent skills are required and the capacity to accomplish the task. It has been observed that Disabled Persons usually prefer to work at tasks where minimal adaptations are required, thus permitting a more ''Normalized'' setting, if this does diminish their productivity.

Atthe Quebec Paraplegic Association, we believe in this approach: the less special adaptations the better. After rehabilitation, having measured one's physical abilities, what can be wished for and done in terms of work ?

In searching for work, we have found that the following criteria come first and formost: motivation, skills and the market place. Adaptations and special equipment to a work station are in the last deciding factors. Our Vocational Counsellors have found this to be true, time and time again.

Also adaptation to work stations and special equipment require time and money, specialists and evalutions which can slow down the hiring process and scare many employers, who often have barely become aware of architectural access and adapted transportation.

Through vocational counselling,Disabled Persons make their choices based on their skills and the demands of the market-place eventhough technology could offer them more ease and productivity. From the hand to the electric typerwritter to micro-computers to robotics: the hand is still so very important, whatever form or limitations it takes.

If technology is not essential for persons with lesser disabilities, it has been for others with more severe disabilities, THE only way for them to ACCESS WORK. For example, high level quadraplegics can now enter the work force through training and use of compuers and hand-free phones; also the recent advances in decoding and communication equipment have given the Sensitory Disabled, greater choices in carreers. In the future we hope that attitudinal changes in the market place, will permit more and more choices in where, how,when, people will work. Working at home in work shops, or hospitals, people linked to companies by electronic and telecommunication means. An open and extended work place.

We recognize the great input of technology to ACCESS WORK when it achieves what would have been impossible without it. Its development should always aim to serve all of humanity disabled and able alike, making work more efficient, improving working conditions and ultimately improving the quality of life. In this direction it raises questions as to the sense of work, which is essentially an organized social concept of activity. And activity remains self-realization. Work is human activity and technology is at its service.

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THEME SESSION/
SESSION THÉMATIQUE A

Ageing
Vieillissement

ICAART 88 - MONTREAL

WANDERING: THE PROBLEM

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INTRODUCTION

In January of this year, the Atlanta Journal and Constitution reported the death of a 71 year old man who had wandered off from a local general hospital and been missing for several days. His body was found later, partially submerged in a creek.

A similar incident was reported in the Milwaukee Journal a few years ago when an older man wandered from a nursing home and died from exposure. This led to a lengthy litigation and the filing of criminal charges against the nursing home director for neglect.

A topic of an Oprah Winfrey Show earlier this year was Alzheimer's disease. On the panel was an older couple who had gone to New York City to visit relatives. The woman, who had Alzheimer's disease, was separated from her husband on the subway and was lost for three days. When found by her husband, her pocketbook was missing and she had on a different set of clothes. Obviously, wandering is a serious problem for all concerned, the wanderer, their relatives, and caregivers.

Definition of Wandering

As in the case of any complex behavior, objective definitions of wandering have been difficult to formulate. Definitions of wandering have been of two general types, 1) behavioral/descriptive and 2) cognitive [1]. Examples of the former include: "spending proportionally more of one's wakeful time in motion than does the average patient or resident"; being in areas considered unsafe or extremely bothersome by caregivers; a change in physical location which results in the inability to return [2]; or into the rooms of other residents. In each of these definitions, the movement or behavior of the wanderer is the focus, rather than assumed purpose. Factors which underlie many of the attempts to behaviorally define wandering are the amount, type, location of movement, the degree to which movement places one at risk for injury, and the degree to which caregivers must intervene once wandering occurs.

Definitions based on a cognitive interpretation often "link the concept of 'wandering' to the value judgement of 'aimless'" [3]. However, descriptions of wandering episodes by caregivers typically include references to the purposefulness of the activity, e.g., the desire to go to work, home, or just to get out for some fresh air.

Scope of the Problem

Estimates of the incidence of wandering behavior in institutions range from as low as 6% to as high as 18% [1,3]. Differences in estimates are likely due to definitional inconsistencies or particular sample characteristics [3]. Within the VA nursing home in Atlanta, 10% of the residents of the 120 bed facility were judged to wander by the nursing staff. Based on the estimates quoted above, between 85,667 and 257,000 individuals exhibit wandering behavior in the United States. The Research Triangle Institute [1] makes the point that "although a minority of patients wander, the number is substantial, and the impact of their wandering on long-term care costs as well as on quality of life and other outcomes is substantial." The financial burden on the relatives of wanderers is substantial since exhibition of wandering behavior typically leads to earlier nursing home placement and hence increases long-term care costs [3].

Dementia and Wandering

Dementia with accompanying memory loss is probably the most frequently cited correlate of wandering. Hiatt [3], in her survey of nursing home directors, found that 54% reported senility or dementia as a "cause" of wandering.

Dementia typically results in a general deterioration of intellectual functions. In addition to impairment in attention and memory, there is usually impaired abstraction and judgement, cognitive deficits, and personality changes [4]. Wanderers as a group have been described similarly, having a short attention span, to be restless, easily distracted, and to have difficulty following directions. They perform poorer than non-wanderers on mental status evaluations, particularly with regard to recent and remote memory, orientation to time and place, and the ability to respond appropriately to a given topic. From the above, it appears that a deteriorated cognitive status and wandering behavior are related, however, to what extent remains to be determined.

Impact on Caregivers and Wanderers

Wandering, like all pathological behaviors, places a severe strain on the families of older individuals. Frequently it occurs at night or the early hours of the morning and thus requires constant vigilance by family members. Twenty-five percent of a sample of caregivers who provided primary care for their relatives afflicted with Alzheimer's Disease (SDAT), mentioned problems related to the need to constantly watch them for fear they would "wander off and get hurt. Wandering behavior was cited by these caregivers as a primary problem as frequently as incontinence and feeding difficulties [5].

Treatments for Wandering

Though wandering is frequently referred to as a complex, often uniquely expressed behavior the most frequently employed interventions appear overly simplistic. Intervention typically includes physical (geriatric wheelchairs, enclosed courts, dutch/half bedroom doors, locked unit bean bag chairs) or chemical restraint (medication) of the individual or caregiver monitoring of the wanderer's location in the environment to prevent elopement. Behavioral methods are often effective but rarely used.

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WANDERING PHENOMENA: THE PROBLEMS AND SOME SOLUTIONS

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INTRODUCTION

Wandering phenomena are stylized patterns of walking or wheeling typically accompanied by faulty judgment regarding risk, direction, return route, location, or duration of the motor activity. Examples range from pacing and rummaging to attempts to leave and roaming (Hiatt, 1985).

This paper focuses on unmet needs of older people and of caregiving systems: households and institutions attempting to accommodate the value of motion and mitigate the risks of people who lack judgment moving about.

METHODOLOGY

This paper is based on:

1. Computer aided literature searching;
2. Unpublished and limited circulation research on wandering obtained through personal contact with four other research groups including those involved with the Veterans Administration, National Aeronautical and Space Administration and with organizations in the U.S. and Canada.
3. Personally conducted empirical research including a 1976-9 study of 39 wanderers (Snyder, et al., 1978); a 1980 study of 19 wanderers on a psychiatric hospital and a comparison group of non-wanderers (Hiatt, 1981); and a 1984 study of wandering in 170 U.S. nursing homes.
4. Follow-up contact with researchers developing technology.

BACKGROUND

Several independently operating researchers have recently asserted that wandering is NOT aimless in the sense of being without value (Hiatt, 1985; Hussian and Davis, 1985; Burnside, 1980). Based upon the observations of caregivers, many older people who wander have a goal or destination in mind. For others, the motion itself is the goal (Hiatt, 1985).

Once medications are ruled out as a factor in wandering, it is estimated that an institution may have between 11%-16% of the elderly clients who wander at any given time. A much smaller proportion leave. This does not include the 24% who are spatially disoriented or unable to find a goal or follow a route. The problems posed by wandering stem from the risks and consequences of unpredictable actions of people who MAY lack judgment and the time-con$uming vigilance demanded of responsible caregivers.

The motion associated with wandering may not in itself be a problem; in fact, for some people, the motion may dissipate precipitating emotional conditions such as agitation or pent-up energy.

There appears to be no single treatment for the different styles and patterns of wandering (Hiatt, 1985; Hussian, 1981). We need more research on motoric behaviors and on appropriate techniques of evaluation. One of the real weaknesses in both the available empirical research and the interventions (including technological systems) is that wandering phenomena are treated as though all motion, judgment and environments posed the same set of risks and warrant the same interventions. Individual assessment and intervention would be preferable.

The tendency in too many institutions, has been to confine and restrain people who exhibit the tendency to move more than the norm for their peers. In part this grows out of misdirected concerns with risk management and falls. Evidence from Canada, the U.S. and abroad suggests that physical restraints may increase the risk of falls and associated injuries (Canadian Nurses Association, 1980). People determined to leave or vulnerable to "slipping away" seem unhampered by belts, restraining chairs and combinations of these techniques.

STATE OF INTERVENTIONS

Until about 1985, few institutions dealt proactively with wandering. Three factors have produced a change: 1) a more habilitative approach to Alzheimer's disease, 2) liability, and 3) breakthroughs in monitoring technologies. Now, interventions tend to be of four types (Hiatt, 1985): 1) enriched programs; 2) better vigilance; 3) environmental cues; 4) perimeter control and personal security systems. None of these have been adequately studied in or adapted for people at home. There are a host of practical techniques used to redirect behavior, diffuse agitation, protect the privacy of others and improve personal identification (Hiatt, 1985. Almost anything seems to work better than benign neglect. Restraint, bean-bag chairs, reality orientation, color coding and behavior modification have NOT had a major impact on wandering.

DIRECTIONS FOR INNOVATION

Both social and technological innovations need to be based on several premises which to date have not been adequately addressed:

1. There are different styles of wandering as characterized by: emotional state, judgment, pattern of movement. We need more research on the behaviors themselves.
2. Certain building features seem to magnify or to reduce the problems of wandering. We need better means of assessing these.
3. Technology should be adapted to a combined understanding of the residual skills of the individual, the roles and risks of wandering to him or her. We need a range of methods.

Technology has been developed for monitoring and mapping a person who runs away (see Coon, 1988). Such systems are worn by a known wanderer. We need interventions that:

1. Improve our response to first time elopement from institutions, especially for those who would leave a perimeter of safety. These systems might be video based.
2. Are tiny in size and unnoticable
3. Are low in cost.
4. Can be used at homes, public places and in institutions.
5. Are responsive to different patterns of wandering.
6. Do not necessarily curb movement, but rather keep the individual in a safe zone.
7. Provide feedback to caregivers regarding fatigue or other physical changes warranting rest.

REFERENCES. Due to space limitations, references available on request from:
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WANDERING SEQUENCES AND BEHAVIORAL INTERVENTIONS IN OLDER PEOPLE

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INTRODUCTION

Wandering is a serious problem for both caregivers and elderly people who exhibit the behavior. The term *wandering* has "been applied to behavior as different as pacing, trying doorknobs, entering other people's rooms, talking about going 'home,' attempting to leave or leaving an institution against advice, getting lost on a walk, or simply talking in a way that someone considers disoriented" [1]. Even though this confusion of definition makes diagnosis and treatment of wandering difficult, it does not make the phenomenon *less real* or *less of a problem.* Problems of definition stem from the fact that studies, to date, have not focused on the actual sequences of behavior which precede and follow exiting attempts.

Nursing care facilities have treated wandering by increasing medication or using devices which restrict movement or alert caregivers that an older person has left the nursing home [2]. Warning systems offer individuals who wander increased freedom of movement. However, none of the alert devices presently on the market provide feedback to the wanderer that might alter their pattern of movement. The automated delivery of feedback to older people that would reduce their wandering behaviors represents a technologically more sophisticated and humane solution to the problem of wandering. We are currently studying the feasibility of such solutions.

The purpose of this study was twofold. First, in order to remedy problems of definition, a systematic observational phase focussed on the description of the sequences of behaviors which constituted wandering episodes. During this phase, reliable and relevant scoring categories were developed from video recordings of actual wandering episodes. Second, an intervention phase focussed on whether specific wandering behavioral sequences could be altered by the use of computer generated verbal feedback. Symptom substitutions as a response to the intervention were also evaluated.

METHOD

Subjects

Subjects were 30 older residents of a large metropolitan nursing home. Subjects had been required to wear electronic detectors because they had been identified as "wanderers or potential wanderers."

Setting and Instrumentation

The majority of the exits at the nursing home were restricted (opened only with a fire alarm). Frequently traveled exits were electronically monitored with a wanderer alarm system (e.g., the main entrance).

Cameras and a sophisticated detection system were installed at the unsecured exits at the nursing home, as well as near the open areas on residential floors. Cameras were activated as study subjects traveled from their floor of residence toward monitored exits. Each camera was connected to a time-lapse video recorder and detection equipment interfaced with a computer.

Design and Procedure

All subjects were evaluated with regard to background information and a weekly review of medications dispensed. The subjects were also administered a psychological test battery by a certified psychometrist which included standardized instruments to assess dementia, memory function, and depression.

Phase 1 For a period of four weeks, the behavior of the subjects was videotaped when monitored by the detection system. As data were generated, tapes and computer logs were reviewed on a daily basis. Descriptive categories and a code catalogue were developed and wandering sequences were scored according to this catalogue by two trained raters. The catalogue included codes to capture substitutional behaviors that occurred as a response to the intervention administered in Phase 2.

Phase 2 Similar to phase 1, subjects' behaviors were video taped for four weeks as a function of detection. However, at close range to the main exit (approximately 18 inches) study subjects were presented computer generated verbal feedback instructing each subject, by name, to return.

RESULTS AND CONCLUSIONS

The results of this study will be summarized with respect to wandering response patterns, demographic data, medications dispensed, and psychological impairments. Conditional probabilities, which are the simplest statistic to describe sequential data [3], will be used to describe behavioral sequences of interest, including sequences that end in exiting or symptom substitutions. This information will be displayed in state transition diagrams. The impact of the intervention will be reflected in changes in the transitional probabilities from Phase 1 to Phase 2.

The discussion will focus on strategies for dealing with particular wandering patterns [2, 4] and subject attributes which are particularly problematic with respect to intervention.

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TECHNOLOGY APPLIED TO THE PROBLEM OF WANDERERING BEHAVIOR IN THE ELDERLY

Franklyn Coombs
VA MEDICAL CENTER - ATLANTA

INTRODUCTION

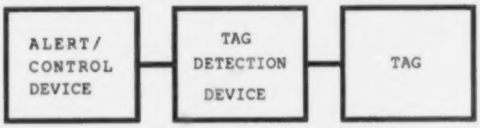
The problem of the elderly person who wanders away from those who care for them, is serious and high technology offers a humane option to methods such as restraint. The annual cost for staff hours spent monitoring wanderers is substantial (e.g., $2,500 per wanderer in the state of Maine [1]).

Institutions have typically responded to wandering behavior by one or more of the following methods: increasing medication, using methods/devices which restrict movement, or the installation of alert systems which inform caregivers that an older person has left the safe confines of the nursing home. Until 1985, two thirds of nursing homes surveyed by Hiatt routinely used restraining methods to control wandering. Less than five percent used the newer signal system technology [2]. This new technology appears to offer a more humane and cost effective solution to the problem.

This presentation will examine the wanderer detection/alert technology presently available. Requests for information were sent to all manufacturers known to the author and this report is based upon the information provided.

SYSTEMS DESIGN

The generic building blocks of a wandering alert system are: 1) the wanderer identification (ID) tags; 2) the tag detection device(s); and, 3) the alert/control device. Typically, one is not free to mix and match components from different manufacturers in order to tailor a system, but must use the options available within a given product line.



Wanderer ID Tags
For any wanderer alert/detection system, it is necessary to distinguish the potential wanderer from the rest of the facility population. This identification is accomplished by the use of a tag, attached to the wanderer, that can be detected by the system. The size and shape of the tags varies, from those that resemble a "thick" credit card to those that are only slightly larger than a half dollar.

The tags themselves may be grouped into three categories, the first of which is the *Transmitter Tag*. Transmitter tags are those tags which continually emit an RF signal to the tag detection unit. When the wanderer wearing these tags come within range of the tag detection unit, the appropriate alerts are activated. The transmitter tag has an internal battery with a typical life expectancy of a few months.

The second type of tag is the *Transponder Tag*. The transponder tag differs from a transmitter tag in that the former contains a receiver circuit as well as a transmitter and battery. The transponder tag is normally in receive mode, "listening" for a signal from the tag detection unit. When a wanderer comes within range of the tag detection unit, the tag receives this cue, or interrogation signal and begins to transmit back to the detection unit. The receive mode can be maintained at a fraction of the battery power needed for true transmitter tags, extending the life of the battery to several years. Both the transmitter tag and the transponder tag can be found in versions that allow the system to uniquely identify each tag. It is also possible to forego this feature and let all tags evoke the same response from the system.

The last category of tags is the *Passive Tag*. The passive tag has no internal source of energy, such as a battery, to wear out. The tag contains a tuned circuit, which is resonant at a fixed frequency. The detection device emits an RF signal that sweeps a portion of the radio spectrum including the resonant frequency of the tag. The detection unit recognizes the variation in the field intensity of its own signals whenever a tag is present. Typically, this type of system is unable to differentiate between tags.

Tag Detection Devices

Tag Detection Devices are the middle link in the wandering system. The detection device has a sensing element which, in the case of RF tags is just an antenna and receiver. The sensing elements themselves come packaged in a variety of forms ranging from ceiling units to door way units to floor mats. Some detection units are capable of simultaneously monitoring two or more zones, and will provide not only the identity of the wanderer in the zone, but the location of the zone as well.

Alert / Control Devices

After a wanderer has been detected in a restricted zone and this information has been forwarded by the detection device, some action must be taken on the part of the alert/control device.

In the simplest case the staff are notified, by means of a beeper or a light at the nurses station, that a wanderer is in a restricted zone. If microprocessor control is introduced into the alert/control device, greater flexibility and enhanced features are possible. Many alert/control units with internal microprocessors will connect by RS-232 to a host microcomputer and the variations on this theme are almost endless.

Patient Locating Devices

If it should become necessary to locate a patient who has wandered into another section of the facility or even away from the facility, there exist systems which can locate the patient by use of the patient's tag. Direction finding equipment, in the form of a portable receiver, locks on to the patients tag and indicates both direction and strength of the signal. With this information one may effectively "home in" on the wanderer and return them to the safety of the facility.

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DYNAMIC POSTURAL SWAY MEASUREMENTS IN ELDERLY FALLERS

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INTRODUCTION

Excessive postural sway or upper body precession from the vertical axis has been directly and indirectly related to falls incidences (1). Prior falls research in the elderly has focused on the identification of risk factors and frequency of falls incidences (2,3). A crucial factor in the avoidance of falls through the maintenance of balance is postural control. There have been studies examining this link between postural stability and fall instances (1,4). This association is further enhanced when the target population consists of older individuals or those with varying degrees of systemic dysfunction (1,2,3). Everyone to some extent exhibits postural sway. It is one of the body's ways of maintaining contact with its environs. Excessive sway, indicating systemic instability, however, could indicate a predisposition to falls. Postural sway and postural instability, to this end, may be couched together.

Sway quantified as postural instability has been typically measured statically. How this relates to sway during ambulation is unknown. Additionally, current literature indicates very little movement towards quantifying sway patterns as to group characteristics or as a diagnostic tool.

Various techniques have been used to analyze sway alone in its relation to postural stability of a subject in a standing position. The ataxiameter (5) and the force-moment apparatus examine postural stability relative to a fixed time frame. Various permutations of the force platform used projections of the center of gravity as sway indicators (4). These static measures examined sway alone. Various kinematic techniques have been used to facilitate the study of human movement. Photographic and mechanical methods have served to categorize this movement on the basis of center of gravity trajectory and velocities. These studies however, have not been cited as being useful in the analysis of sway.

This study addresses the use of a triaxial accelerometer based system that is designed to measure the precession from the vertical axis, in the medio-lateral and antero-posterior planes. The detection and quantification of postural sway can be used to predict the potential for falling based on the contribution of floor surface resilience and physiological stability. Quantified measures of dynamic postural sway can be used to develop characteristic profiles of baseline and comparative floor surface data. This, in turn, could provide insight into the effect of floor surfacing on postural instability.

METHOD

Instrumentation

A simple yet adaptive system was developed providing for the dynamic analysis of postural sway. This system consists four primary components: and Entran triaxial accelerometer, its associated signal amplifiers and power supply, and and IBM PC/XT microcomputer. The former two are worn by the subject in a belt/backpack combination, while the latter two are located on a laboratory benchtop. Figure 1 provides a simple schematic of the system.

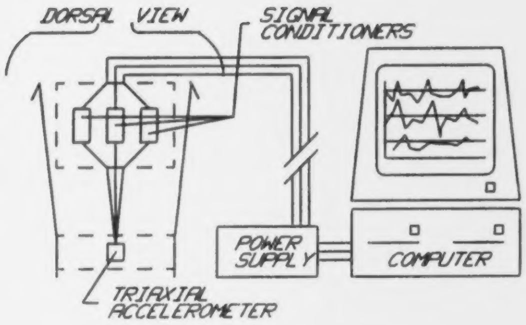

Figure 1. System Schematic

Accelerometer The accelerometer is attached to a belt worn around the waist and located posteriorly at the upper portion of the sacrum or lower lumbar region, thus in close external proximity to the subject's center of gravity. The center of gravity is the most stable point of any body in motion. The triaxial accelerometer uses inertial loading of small cantilever beams equipped with strain gages.

Data sampling Through the use of sampling circuitry, it is possible to obtain discrete values from the continuous accelerometer data. These data may then be treated in various ways by programming the personal computer. Filtering of experimental data is often necessary to remove signal noise. Digital filtering removes noise from discrete data signal by creating a new signal which consists of a combination of data values from points on the original signal and preceding points on the filtered signal. A simple algebraic relationship between the two signals produces the new signal and may be obtained using simple computer programming. Fourier analysis of the signals permits identification of harmonic frequencies in repetitive motions.

Procedure

Testing of the system consisted of a three phase protocol. The first phase focused primarily on equipment validation in the laboratory. This testing occurred at both the hardware and software levels. The second testing level involved in house subject tests. The subjects were informed of the testing procedure and then outfitted with the device. Allowed several practice runs, the subjects were instructed to ambulate in their normal mode without gross exaggeration of movement. Data was then captured. These tests were run on a concrete flooring surface. The protocol for the third phase was identical to the second phase except various floor coverings were used versus the concrete in the previous study. Total testing time took approximately 15 minutes per subject.

RESULTS/DISCUSSION

The results of these preliminary tests will be summarized with respect to intraindividual sway pattern variations resultant from the various floor coverings. Full analysis of the in house preliminary testing was incomplete at publication. Discussions of test results will be presented at the ICAART Proceedings.

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TOWARDS THE EMPATHETIC STAIR: A REPORT OF WORK IN PROGRESS

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Deborah Hyde, Georgia Institute of Technology

INTRODUCTION

The average number of accidental deaths that occurred every year in the U.S.A. from 1976-1980 was 103,905. Of these, accidents by falling were the second largest cause of accidental death amongst men and women in all age groups. The average number of deaths due to falls from 1976 to 1980 was 13,320 (Accident Facts, 1981).[1] Data from the late 1970s indicates that 12 million persons suffered injuries from falls that were serious enough to cause at least one day's absence from work, or required medical care--a record not matched by any other type of accident. Approximately 3 million people suffer from back trouble, leg and arm trouble and trouble to other parts of the body as a result of falls.

Falls are the fifth most common cause of death. In terms of accidental death rates, falls are second only to motor vehicles. About 10% of fall accidents are "falls on stairs" and 80% of these happen in the home. In 1980 of the 12,300 deaths resulting from falls, 6,700 (54%) occurred in the home. (Accident Facts, 1981).[2] In 1976, in the U.S., more than half a million people received hospital treatment for injuries resulting from stair accidents and approximately 4,000 people died (Archea et.al., 1979).[3] Stair accidents which are serious enough to disable the victim after the day of the fall amount to between 1,800,000 and 2,660, 000 per year. If we express these stairway accident figures in epidemiological terms, then we are describing an epidemic of considerable magnitude.

At present, there is no developed theory of building falls. It is the purpose of our research to develop a theory of building falls and particularly stairway falls, to generate computer simulation models of these falls, and to investigate the feasibility of injury reduction techniques. Although the study is directed at stairways, the general theory should be adaptable to many other types of building falls -- falls in bathtubs, on ramps, off furniture, in kitchens and so on.

Our specific goals are as follows:
(1) investigate the factors which constitute normal gait on stairs and ramps; (2) identify the conditions which cause dysfunctional gait; (3) describe the mechanics of falls on stairs (in ascent and descent); (4) examine the relationship between the factors which cause dysfunctional gait and the resulting body motions terminating at impact; (5) identify the parts of stairs that cause injuries; (6) identify design factors, and energy absorbing materials to vitiate the forces of falls and reduce injuries.

METHODS

To address these questions our research is divided into six (6) phases which are part of a grant from the National Science Foundation.

(1) Collection and analysis of available stairway fall data relating to causes of dysfunctional gait.
(2) Characterization, by experiment in the laboratory, of realistic body kinematics at fall initiation, using human subjects.
(3) Computer - based simulation of the free-fall and impact stages of stairway falls.
(4) Modification of computer models using data from the laboratory tests.
(5) Testing of materials and assessment of their energy-absorbing capabilities.
(6) Verification and modification of the computer models.

The second phase, the human subjects experimentation phase, was developed based on the work of Lennart Kvarnstrom (1973)[4] who attempted to increase our understanding of stairway falls with the use of a laboratory "trick stair". Several of the steps of this trick stair could be released to give a trap door effect, thus triggering a supporting guy wire to prevent an actual fall from taking place. However, these sensible precautions prevented the researchers from learning much about the trajectory of falls. None of these approaches are fruitful for our purposes, so we have, constructed a trick stair in which we can trigger the typical types of accidents that have identified in Phase 1. The trick stair has for example, stair nosings that can be raised to cause trips, stairs treads that fall away to cause missteps, and so on.

SUBJECTS

Fifty subjects will be asked to ascend and descend a single flight of stairs. These five trials will be repeated three times on different occasions, at some time during the last five trails, the trick stair will be activated causing the subjects to lose their balance. Using the safety systems, the subjects will be prevented from traumatic impact with the environment fall initiated. This fall information will be recorded on film during the stair use. The changing positions of the subject's joints during the falls will be digitized, and extrapolations estimated. This data will be utilized to modify the computer simulation models (Phase 3) to provide a reasonable accurate picture of stair falls from which the magnitude of the impact forces can be established. Once the magnitude of the forces has been established, practical materials can be evaluated to ensure that in the future stairs can be constructed, like the interior of automobiles, to obviate the most serious effects of an accident.

RESULTS

The dual goals of this preliminary research are to develop an accurate and realistic model of stairway falls and identify design factors & energy absorbing materials to vitiate the forces of falls and thus reduce injuries. The theoretical model of falls developed from a computer model is a mathematical expression which describes the fall in relation to x-y axes. Specific results are not available at this time as it is an ongoing project. Data from the laboratory induced falls will become input to modify the estimated limits expressed in the mathematical model. This model will then provide a close approximation of the magnitude of the impact forces that must be attenuated through a redesign of the stair components.

DISCUSSION

To date we have completed the following tasks:

- The computer model is operative
- A method for measuring energy attenuation of materials have been developed and some candidate energy-attenuating materials are being compared
- The stairs, which are a highly complex, pneumatic piece of machinery, and currently undergoing preliminary testing and evaluation prior to actual subject testing.

We hope to be able to report the complete study results within the next six months.

CONCLUSIONS

Completion of all six phases outlined above will establish a verification loop for the many models, analytical, numerical and physical, employed. If the modeling is adequate, a realistic statistical distribution of input to the computer simulations should predict a realistic statistical distribution of injuries. Tools necessary for exploring ways to reduce stairway injuries will thus have been established.

ACKNOWLEDGEMENTS

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TECHNOLOGY USED TO MOTIVATE OLDER PERSONS TO EXERCISE

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Gerald Fletcher EMORY UNIVERSITY
Art Koblasz GEORGIA TECH.

INTRODUCTION

The value of exercise in maintaining good health has been well established. The problem most people have is that exercise is usually solitary and boring! This project is evaluating different feedback techniques to determine if an interactive video/exercise system will motivate older people to exercise more regularly than those using standard exercise equipment. The object of this study is to determine if such methods will improve the commitment to exercise, and not to develop new equipment.

SYSTEMS DESIGN

The first phase of this project is to modify the standard exercise equipment to allow feedback control of the load, and thereby control the rate of exercise. The basic scheme for each system will be the same; a target heart rate is entered in the computer control and the computer varies the exercise load to maintain the heart rate. Different motivational schemes will be evaluated. The simplest is audio feedback; i.e., music. Next will be a video game, where gremlins chase the subject's character on screen. Maintaining the target heart rate allows the subject to run over the gremlins; different paths on the screen change the work load.

The most complex interactive system will use video disc technology. This system will use a large screen (36 in.) projection TV in front of a modified Schwin Aerodyne exercise bicycle. The subject's heart rate controls the the subjects apparent speed and position within two groups of bikers racing in a scenic area. The computer can make the video disc presentation appear to move in relationship to the subject, without the obvious jerky motion of fast forward on video tape.

The riders on the video disc will start in two groups; one group in front of the other, The subject will be between these groups for a warm up lap, then the "race" begins. Stereo sound will be used front and back, as opposed to left and right. The riders in front will turn their heads regularly (as they do in a race) and different audio messages will be inserted by the computer. These messages are intended to encourage the subject and add some realism; i.e., bicycle tire and chain noises with riders huffing and puffing. As the subject maintains the target heart rate for longer periods, the computer will move the subject up in the pack, and the other riders will appear to react with the computer adding in voices saying statements such as "hey, the guys catching up" or "work harder you guys - he's going to beat us."

The hypothesis is that the apparent competition will motivate people to exercise more often and at their target rates for optimum periods. The project will evaluate preferences between the exercise systems; comparing their choice between standard equipment, simple audio feedback, the video game or the competitive system. Regularity of exercise over a one year period with the specialized equipment will also be monitored. The presentation will describe the adaptation of the equipment, the video disc technology, the subject selection criteria, and the exercise protocol.

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VIDEO RECORDING OF FALLING IN THE ELDERLY

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INTRODUCTION

Falls and unsteadiness of gait are major problems faced by many elderly people. With the exception of some stairway accidents, there are no actual recordings of falls of elderly people. The lack of a clear objective record of falls has limited the ability of researchers to determine the most significant factors to study in order to more effectively contribute to prevention.

METHODS

A recording system consisting of 4 video cameras and 5 videotape recorders controlled by a Commodore 64 microcomputer is being used to continuously record activity in the lobby areas at a geriatric complex. The computer automatically starts and stops the video recorders between the hours of 0600 and 2100 daily. The videotapes continuously rewind and tape over earlier material, except for the two hours leading up to the fall. Whenever a fall occurs, a member of the staff activates a switch located on the back of the computer cabinet which causes all of the tape drives to stop. The times for rewinding the tapes are staggered. During each tape rewind, the computer switches to the fifth videotape recorder to maintain coverage with all 4 cameras. A battery backup of approximately two hours operates at any power outage. A voice synthesizer puts the time on the tape each 15 seconds, so that the fall time can be retrieved quickly and observed on the 5 tapes for the 4 camera locations.

The video record of the fall is subjected to a detailed analysis by a multidisciplinary team.

RESULTS

During the first 8 months of the study 13 falls have been captured on videotape. All of the fallers who were identified were residents of the home for the aged portion of the complex; their average age was 86 years. Two of the fallers were unidentified visitors. Videotape stoppage occurred for a further 7 falls; however, due to equipment malfunction or location of the fall outside the surveillance area, these falls were not available for analysis. The stop button was not operated on a further 3 occasions.

The falls were classified into those resulting from environmental conditions (N=5), behavioural factors (N=1), and intrinsic factors such as disease processes (N=7). Several types of falls were postulated from the videotapes, for example: collapse (N=1), topple (N=2), trip (N=2), slip (N=1), dislocation (N=4), and mislocation (N=3). The videotapes of falls provided the opportunity for repeated examination of the fall in every event and in 2 cases, they were the only record of the falls. The videotape of the fall conflicted with the report of the resident or the staff in 3 instances, even though every attempt was made to provide an accurate account of the fall.

The videotapes were of insufficient quality to examine such details as facial expression or foot clearance; the distance from the camera to the fall ranged from 5.6 to 26 metres.

Case presentations

Falls associated with elevator use are common in this institution (1). Two such falls by elderly women, on separate occasions, were observed on tape. Each woman exited the elevator; the walking frame preceded her through the elevator door when suddenly she was knocked over. Each of the fallers reported that the door closed on her before she could get out, but this could not be verified on tape because of the acute camera angle. Contrary to the resident's account of the fall, the multidisciplinary team suggested that one fall may have been a "trip" where the foot or walker caught in the elevator/floor gap. The latter woman was seen to "roll" onto the floor and maintain a hold on the walker. The faller tried to protect herself by extending one arm, but was unable to prevent the fall or prevent the subsequent elevator door closure.

Intrinsic factors appeared to be responsible for the falls of 2 elderly men. One man with Parkinsonism exibited classical Parkinsonian gait: flexed posture, walking on toes, short shuffling steps, and festination. He gradually increased speed to the point that he appeared to be running to catch up to his centre of gravity; he fell just after passing through a brightly sunlit area of the lobby. This man showed protective arm reflexes in an attempt to break his fall.

VIDEO RECORDING OF FALLS

An error of motor control has been suggested as the cause for 2 falls of an elderly gentleman with diagnoses of tardive dyskinesia and cognitive impairment. Both falls occurred in the same location. In the earliest fall, he was sitting on a bench-type seat without armrests. He was seen to cross and uncross his legs several times. He shuffled a little to his right with each repeated movement until he fell off the end of the bench. He raised his left arm to counterbalance the dislocation of his centre of gravity. He claimed to have been pushed off of the seat. The next fall occurred when he was standing; he exhibited a similarly repetitive purposeless activity of shuffling his weight from foot to foot and reaching in and out of his pocket, prior to bending forward in what appeared to be an attempt to put something he found in his pocket into an ashtray. He slightly flexed his knees and hips as if to commence sitting, but suddenly fell backwards onto the floor, maintaining this crouched posture.

DISCUSSION

The surveillance system is of no value if the videotape stop button is not pressed when a fall occurs. On 3 occasions, falls were missed because the stop button was not activated. An extensive publicity campaign was launched at the initiation of this project. The surveyed areas were posted with signs describing the "Freeze That Fall" project, and staff meetings were held to explain the reporting process for a fall in the area.

Videotaping may be considered to be an intrusion of privacy. Ethical approval for the surveillance was easily obtained on the basis that the system automatically tapes over previous material. Once a fall has occurred, the researchers retrieve the videotapes and approach the faller(s) to seek consent to examine the tapes. If consent is not given, the tapes are erased.

The ability to review the fall repeatedly provides greater opportunity to examine the factors related to falls in these elderly subjects than has been previously available. The fall reports compiled from both the staff observer and faller information often differ from what is observed on the videotape image of the fall incident. This discrepancy of information confirms earlier studies that question the accuracy of information collected on fall reports (2).

The causes of falls, as detected from the videotapes, are complex. The contribution of an environmental factor such as an elevator door must be discussed with consideration of such issues as: the mobility of the elderly person, the type of footwear worn, the physical operation of the door including the mechanism to keep the door open, and the characteristics of the gap between the elevator and the floor.

Six types of falls have been observed; collapse, topple, trip, slip, dislocation, and mislocation. Dislocation is an externally-generated disruption of balance, such as by a push. In contrast, a mislocation is an internally-generated error in body placement, such as misjudging the location of a chair during ingress. This classification may provide insight into the causes of falls and the relative contribution of environmental, behavioural, and intrinsic factors.

It is planned to introduce additional cameras to provide better images, reduce the distance to the fall areas, and to examine other high risk locations. Post-processing of the images may assist the examination of more detailed events such as foot clearance or the rate of reflex movement.

CONCLUSIONS

Videotaping falls of elderly people in an institutional setting has been successful, and has provided a permanent record of falls due to a variety of factors and in many circumstances. This approach might be applicable to other situations where examination of accidents may be beneficial.

ACKNOWLEDGEMENTS

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THE SMART HOUSE PROJECT

By

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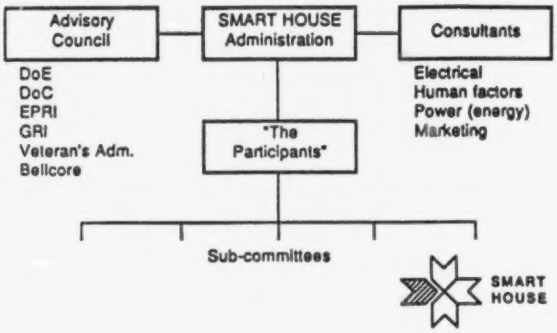
Ottawa, Ontario

Abstract

The 'Smart House' is a major attempt by the United States building industry to provide houses which are safer, provide more flexibility in voltage supply and control and offer broad communications capability both round, and into and out of the house.

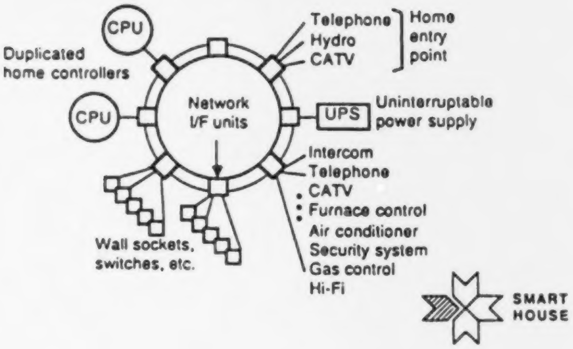
Smart House is a recent innovation in house design which combines the centralized microprocessor control of building systems and household appliances with the unified distribution of power and communications. Its evolution as a viable concept is being spearheaded by the United States National Association of Home Builders Research Foundation.

THE VENTURE


Advisory Council
DoE
DoC
EPRI
GRI
Veteran's Adm.
Bellcore
SMART HOUSE Administration
Consultants
Electrical
Human factors
Power (energy)
Marketing
"The Participants"
Sub-committees
SMART HOUSE

Companies that are involved in the Smart House endeavour number more than forty and include AMP, Square D, AT&T, Honeywell, Apple, Carrier and General Electric. Collectively these companies represent the varied interests of telecommunications, appliance manufacturing, computer processing, security, and home entertainment.

By limiting the number of participating companies, NAHB offers a competitive edge in the market place to those companies



THE SMART HOUSE
GENERAL ARRANGEMENT

CPU
Duplicated home controllers
CPU
Network I/F units
Telephone
Hydro
CATV
Home entry point
UPS
Uninterruptable power supply
Intercom
Telephone
CATV
Furnace control
Air conditioner
Security system
Gas control
Hi-Fi
Wall sockets, switches, etc.
SMART HOUSE

receipt of power would be required for the supply of power to be maintained. This unique approach to the distribution of power and signalling distinguishes the Smart House concept from other attempts at home automation, and as a demonstration of support, the National Electrical code has agreed to twelve essential code changes, as options from 1987.

The basic features of the Smart House concept are therefore as follows:

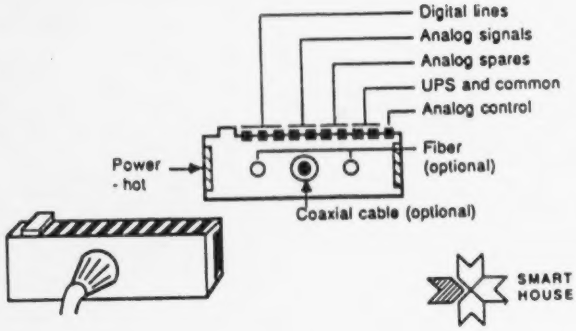
a) A 'closed-loop' control that monitors and controls energy flow.

b) 'Programmed-power', allowing a.c. or d.c. to be selected.

c) A communications network that permits the remote control of appliances and devices and the transfer of information.

d) A unified wiring scheme that simplifies the addition of new types of appliances and devices at a future date.

e) A gateway that can transfer information to locations outside the home.



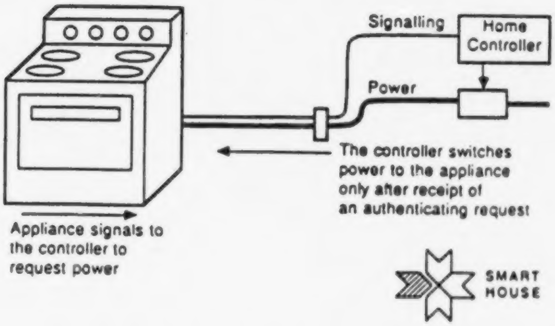
SERVICE INTEGRATION
- THE SMARTHOUSE PLUG AND SOCKET

Digital lines
Analog signals
Analog spares
UPS and common
Analog control
Fiber (optional)
Power - hot
Coaxial cable (optional)
SMART HOUSE

The market for Smart House in the U.S. is directed towards the 1.5 million new homes contructed annually. Initially, the cost of wiring the Smart House is expected to be a few percent above that of conventional wiring, but is ultimately wishing to invest in the concept. NAHB is itself has over 142,000 member firms which represent about 90% of the residential, light commercial and industrial construction market in the United States.

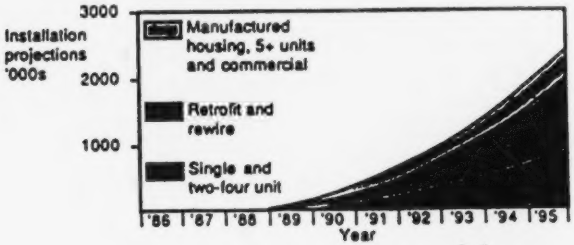
The control of appliances such as refridgerators, stoves, dishwashers, clothes dryers, stereos and television; and building systems such as furnaces, air conditioners, humidifiers, fire detection devices and security alarms would be handed over to the central processor unit, with any information considered pertinent to the operation of the device and supplied to the central processor by means of an associated micro-chip within the appliance. Such information would include the power requirements of the appliance, such as current (a.c. or d.c.), voltage, and normal operating current limits. The performance of the device could be similarly monitored by the central processor and an operational record kept for maintenance purposes. In the event of problems with the appliance, a trouble report could be initiated and if necessary the circuit de-energized.

THE CLOSED LOOP 'SAFE' SMARTHOUSE POWER SYSTEM


Signalling
Home Controller
Power
The controller switches power to the appliance only after receipt of an authenticating request
Appliance signals to the controller to request power
SMART HOUSE

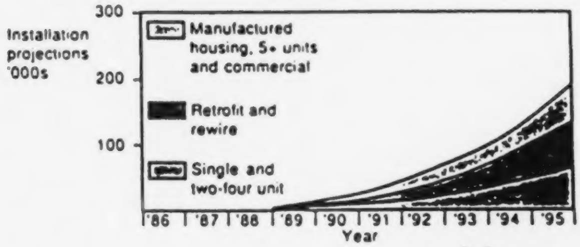
Cabling for the relay of telephone, video, power, alarm signals, and stereo would be fully integrated using a combination of twisted copper and coaxial cable terminated at a single receptacle. Safety is claimed as a major advantage of this approach to power because outlets would be dead when not called upon to feed an appliance. The chance of electrical fire and accidental shock would therefore be reduced. Furthermore, the internal network would be 'closed-loop' in that a signal from the appliance would be required before power could be supplied to the appliance and a subsequent signal from the appliance acknowledging the expected to generate savings as the concept matures and the economics of scale take effect. It is acknowledged that the driving forces behind the Smart House concept are the desire of the home owner for enhanced entertainment, and the desire of the home builder to provide value added service.

PROJECTED SMART HOUSE INSTALLATIONS IN U.S.A.



The current schedule for Smart House calls for the construction of a number of prototype houses in the Washington area for the spring of 1989. In the interim, two mobile units have been constructed for demonstration purposes, and are currently on tour throughout the U.S. and Canada.

PROJECTED SMART HOUSE INSTALLATIONS IN CANADA



A combination of forces - the National Association of Homebuilders as sponsors, major industry support, large venture capital investment, the new National Co-operative Research Act and the recent modifications to the National Electrical Code to permit the concept, all seem likely to ensure the success of the 'Smart House' project.

Bell Canada are monitoring possible telecommunication service opportunities represented by the Smarthouse project. Bell-Northern Research cooperate with them as members of the Advisory Council.

INTELLIGENT HOUSES FOR THE ELDERLY

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INTRODUCTION

Intelligent housing for older people? --If we're so intelligent, why defer the delights of everyday life to someone, say nothing of some "thing." Clearly, the dreamers and marketers who envision smarter environments will have a job convincing owners of today's frustrating appliance, autos, watches and video equipment that greater technology will yield a better product. What makes intelligent housing worth thinking about? And if we were to find sufficient numbers of consumers over 70 who'd be interested in intelligent houses, is there any evidence that they could afford it?

BACKGROUND

The notion of intelligent environments has been promulgated by those interested in energy conservation and construction. For example in the U.S., the largest membership organization of home builders, the National Association of Home Builders, set up a separate corporation called "Smart House" tm. This foundation has created two model homes and a plan for environments that use technology in home management. Their notion of Smart House tm involves advances in wiring, systems and appliances that allow pre-programming for 1) turning appliances on or off; 2) managing power load and cycles; 3) powering only well-functioning appliances; 4) diagnosing malfunctioning appliances and systems; 5) sensing, controlling and communicating information on lighting, heating, air quality, noise/sounds, motion, odors and weight; 6) storing information; 7) communicating information elsewhere; and 8) converting information such as sounds to another form such as light.

In 1984, the Smart House tm Foundation commissioned four U.S. gerontologists to contemplate the future of the technology for older people (Hiatt, 1988; LaBuda, 1988; Harris, 1988; Czaja, 1988).

The Smart House tm initiative has several interesting implications. For example, it places emphasis appropriately on people in their own homes. It's exciting to contemplate technologies applied where the majority of elderly live and to look at technologies for every day life rather than medical technology. With these technological possibilities, what might be the actual impact of smarter homes beyond the emphasis on wiring?

1. Sensory optimization: More people would be able use residual senses. Houses could filter noise, air and glare leaving older people the capacity to understand conversation, breath easily and live in surroundings with appropriate visibility.
2. Security: The ability to communicate information on one environment to another provides a non-intrusive security system. My home may monitor my mother's home. Security here may refer to freedom from intruders to the capacity to monitor temperature extremes.
3. Resource Management: Automatically controlled appliances may be a method to diminish energy cost and use, providing the smarter environment is not excessively costly.

In an era where western countries are considering the impact of increased numbers of older people, automated environments may help us to create better, non-labor intensive methods of monitoring rural dwellers, people in their own homes and networking these individuals to some central core of services.

WORK TO BE DONE

1. Human factors researchers, home economists, gerontologists and

economists need to study the impact of intelligent environments. Of all the possibilities, which are most critical? Which are best provided in older vs. newer dwellings?

2. How might we design housing that is "convertible," on a customized basis? allowing the home to accommodate increasing levels of frailty OR be occupied by consumers of varying needs.

3. Developers of dwellings built especially for older people, especially those that are retirement campuses and continuing care retirement communities, would do well to consider some long range uses of retirement communities as a fountainhead of technological services and research.

4. Other social and cultural organizations may be in a position to establish a role in such an intelligent future. We would envision different images of intelligent housing were it sponsored, for example by:

a. family cooperatives or churches such that these entities would use the technology to improve their contact and values.

b. schools such that the technology would be focused on extending qualitative aspects of learning, storing and using information.

c. hospitals such that outpatient services might outnumber inpatient services and provide a balance between "wellness" and prevention and illness.

d. companies and employers offering the intelligent environments as a benefit and a means of relieving existing workforce or connecting to talented retirees.

e. private sectors, such that environments might be developed along themes, allowing consumers to select the aspect of intelligent environments they find most appealing. The Disney model, for example, might focus on the whimsical. The resort model on automation for sports, fitness and hobbies. The mentalist model might operate to expand cognitive functions, supporting memory, responsiveness and conditions of favorable recall. The individualist model might use technology to help people avoid more onerous technologies, using communications and sensory products to shorten distance. The do-it-yourself model might offer vacation camps where people could try out technologies, learn how to use them at home and where to get the money.

I favor the housekeeping and self-repairing model; a housekeeping house would take the self-cleaning oven into the 21st century, freeing me to do more personally rewarding tasks. My neighbor, on the other hand, loves to keep her home. Her preference would focus on assistive appliances.

Most researcher suggest that almost anything is possible. What we need is informed consumer demand and professional input— that is consumers willing to make these technologies theirs. Part of the fear of intelligent homes is that they will usurp the need for individuals or reduce our humanness. But, with greater professional input, we can shape the technology, making it acceptable, user friendly and personally meaningful. We need to go beyond the initiatives of the Smart House tm. Then, too, perhaps it is time to go beyond the notions of an intelligent house and contemplate a more intelligent environment involving many types of environments.

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CLINICAL EVALUATION OF AN EXTERNAL URINE COLLECTION DEVICE FOR NON-AMBULATORY INCONTINENT WOMEN

David E. Johnson [1,2], Jodie L. O'Reilly [1],
and John W. Warren [2]

INTRODUCTION

Many elderly women will not benefit from advances that have been made in methods for controlling urine incontinence. Noninvasive techniques such as biofeedback and bladder training will be ineffective due to cognitive impairment. Adverse side effects and complicating drug interactions may render pharmologic therapy inappropriate. Corrective surgical procedures may be unacceptable to the patient and may be contraindicated because of advanced age. As a result, alternatives for management of urine incontinence of elderly women is frequently limited to use of absorbent products or indwelling urethral catheters. Use of absorbent products is associated with offensive odors and may contribute to tissue breakdown and decubiti. A dynamic and polymicrobic bacteriuria is the inevitable consequence of chronic urethral catheterization.

For men the condom catheter serves as a viable alternative to other methods of urine incontinence management. Although external devices designed to control urine incontinence in women have been reported in the literature, none of those are currently available commercially. We have evaluated a newly developed external urine collection device for women. We believe our results demonstrate that use of this device may be a viable alternative to other methods of urinary care for nonambulatory incontinent women.

MATERIALS AND METHODS

Patients

Seven women, six of whom were in the eighth or ninth decade, participated in the study. Those women were nonambulatory, urine incontinent residents in a chronic care facility. Prior to study, absorbent pads were used for routine urinary care of all patients.

External Urine Incontinence Device for Women

The Female Urinary Pouch (Hollister, Incorporated, Libertyville, Illinois) is a flexible plastic device designed to funnel the urine output through a connecting tube into a bedside collector. Adhesive, similar to that used on ostomy appliances, located around the opening of the device, secured the device to the patient.

Patient preparation included positioning the patient on her back with knees flexed and thighs widely separated, cleansing the external genitalia with mild soap and water, and shaving the mons pubis. The device was positioned onto the patient so that the urethral meatus, vaginal introitus and labia minora were contained within its opening. Once in place, the device was connected to a collection bag for continuous urine collection. Devices were removed by easing the adhesive away from the patient. A water based jelly was used to soften the adhesive bond and facilitate removal.

Study Protocol

Device usage was studied for 10 consecutive days on two patients and 21 consecutive days on five patients. Each device was allowed to remain on the patient for a maximum of 48 hours before replacement, but devices were replaced more frequently if unacceptable urine leakage was detected. Absorbent pads were placed under all patients. Urine leakage, assessed at least once every 12 hr, was recorded as the diameter of the wet spot on the absorbent pads. A wet spot >3 inches in diameter required replacement of the absorbent pad and the device. When devices were removed, the vulva was inspected for adverse reactions resulting from device usage, the external genitalia were washed with mild soap and water, dried with an absorbent cloth, and the replacement device was applied. Adverse reactions were recorded as erythma (0=normal; 1+=slightly pinker than normal; 2+=red; 3+=beet red) and edema (absent or present).

RESULTS

We evaluated 63 applications of the Female Urinary Pouch for 125 patient-days. Through 24 hrs of continuous device usage, only 8 of 63 devices (13%) leaked urine, and only 2 of those (3%) required replacement. Between 24 hr and 36 hr of continuous device usage, urine leakage was detected from 12 additional devices, but only 2 required replacement. Between 36 hr and 48 hr of device usage 11 additional devices leaked urine; 5 required replacement. At 48 hours, when devices were scheduled for replacement, only 14% required premature replacement due to unacceptable urine leakage. The median wear time for devices was 48 hr.

Erythma of the peri-urethral mucosa graded as 1+ was observed following removal of one device (first of five devices applied) from a patient who wore devices continuously for 10 days and following removal of one device (first of ten devices applied) from a patient who wore devices continuously for 21 days. The peri-urethral mucosa of both patients was nonerythematous when all subsequent devices were removed and at the conclusion of the study. More severe erythma was not observed. Peri-urethral edema was observed following removal of three devices (second, fifth and sixth of ten devices applied) from one patient who wore devices continuously for 21 days, but was not present at the conclusion of the study. Peri-urethral edema was not observed on any other patient.

DISCUSSION

An effective external appliance for urinary care in incontinent women may have an important impact on both private and public medical care costs. Since difficulties in outpatient management of urine incontinence is a contributing factor for nursing home admission, an effective external device may reduce demand for nusring home beds by providing a more convenient method of urinary care and thereby preventing institutionalization of women who are urine incontinent. In institutions, use of an external device that would keep incontinent women dry may decrease costs through reduction of supplies, laundry needs and personnel time.

Previously developed external urine incontinence devices for women were held in situ by a variety of techniques including spring tension, a pessary, support underpants, and negative pressure. Efficacy of those devices was diminished by objectionable urine leakage, adverse tissue reactions, and low patient acceptance (1-5).

The Female Urinary Pouch is held in situ by adhesive similar to that used on ostomy appliances, a technological advancement not exploited on devices previously described. Since this adhesive is both biocompatible with mucosal surfaces and effective when damp, it appears to be an ideal material for use on external urine incontinence devices for women. When evaluated in situ for a maximum of 48 hr. only 14% of devices required premature replacement due to unacceptable urine leakage. During evaluation for 125 patient-days, only two incidences of minimal erythma, which disappeared with continued device usage, were observed.

CONCLUSIONS

Results from this preliminary evaluation suggest that external urine incontinence devices held in situ by adhesive similar to that used on ostomy appliances may be a viable alternative method for long-term management of urine incontinence in nonambulatory women. Additional studies for longer, more clinically relevant periods appear to be warranted.

ACKNOWLEDGMENTS

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The role of Biofeedback in Management of Urinary Incontinence

Burgio, Kathryn L.

INTRODUCTION

Urinary incontinence in the elderly is a major medical, psychological, and social problem. Estimates of its prevalence in elderly people living in the community range from 1.6% to 42%[1] and incontinence affects approximately 50% of those in institutions.[1,2] Incontinence is a significant source of dependency among the elderly and costs between $0.5 and $1.5 billion per year in nursing homes in the United States.[3]

This paper summarizes the results of biofeedback-assisted behavioral training in elderly men and women, in women with stress incontinence, and in men with urinary incontinence secondary to prostatectomy.

METHOD

Following medical evaluation, patients completed 2 to 4 weeks of baseline bladder records to document frequency of urination, frequency of incontinent episodes and to identify the events and circumstances associated with incontinence.

Patients attended 1-8 treatment sessions depending on their progress. In biofeedback sessions, bladder pressure was measured using a number 14 French catheter. Rectal (intra-abdominal) pressure and external anal sphincter activity were measured using balloons attached to a rectal tube. During the training procedures, patients received simultaneous, visual feedback of bladder, rectal, and anal sphincter activity. Feedback, verbal instructions, and reinforcement were used to teach patients voluntary inhibition of detrusor contractions and/or selective control of pelvic floor muscles.

RESULTS

Treatment was provided to 39 elderly men and women who were mentally alert and ambulatory: 19 had stress incontinence, 12 had detrusor motor instability, and 8 had urge incontinence without instability. After an average 3.5 training sessions, patients with stress incontinence reduced the frequency of incontinent episodes an average of 82% (range, 55% to 100%). Patients with detrusor motor instability showed an average 85% improvement (range, 39% to 100%) and patients with urge incontinence reduced incontinence an average of 94% (range 83% to 100%).

A second study examined the effectiveness of teaching pelvic floor exercises with use of bladder-sphincter biofeedback compared to training with verbal feedback based on vaginal palpation in 24 women with stress urinary incontinence. Verbal feedback training consisted of instructing the patient to squeeze the vaginal muscles around the examiners fingers and providing her with verbal performance feedback. Biofeedback patients received visual feedback of bladder pressure, abdominal (rectal) pressure, and external anal sphincter activity. The biofeedback group improved the strength and selective control of pelvic floor muscles; the verbal feedback group did not. Both groups significantly reduced the frequency of incontinence. The biofeedback group averaged 75.9% reduction in incontinence, significantly greater than the 51.0% reduction shown by the verbal feedback group. Twelve of 13 patients in the biofeedback group improved by 60% or better. Six patients in the verbal feedback group improved by 68% or better, and five were less than 30% improved. The findings indicate that biofeedback is more effective than verbal feedback based on vaginal palpation for teaching selective sphincter control.

Finally, the effectiveness of biofeedback-assisted behavioral training for post-prostatectomy incontinence was examined. Twenty men with persistent post-prostatectomy incontinence were treated. Initially, scheduled 2-hour voiding resulted in a mean 33.1% increase in urge incontinence, a mean 28.5% reduction of stress incontinence, and no change in continual leakage. Subsequently, biofeedback was used to teach selective control of the sphincter muscles and/or inhibition of detrusor contractions. Individualized home practice included a voiding schedule, sphincter exercises, active use of the sphincter to prevent urine loss, and strategies for managing urgency. Following 1-5 biofeedback sessions, patients with urge incontinence demonstrated an average 80.7% reduction of incontinence; stress incontinence was reduced an average 78.3%; patients with continual leakage were less successful with a mean 17.0% improvement. The findings indicate that biofeedback training is an effective intervention for episodic stress or urge incontinence following prostatectomy. Its usefulness appears to be limited however, in patients with post-surgical incontinence characterized by continual leakage.

CONCLUSION

The data show clearly that for many if not most men and women, behavioral training can be a cost-effective method for reducing stress or urge incontinence.

ACKNOWLEDGEMENTS

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MANAGEMENT OF URINARY INCONTINENCE IN THE ELDERLY: AN OVERVIEW

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Chronic urinary incontinence is a common complication of spinal cord injury, multiple sclerosis, other neurologic diseases, and aging. The latter association assures that urinary incontinence will be an increasingly important problem for health care providers in North America because of the increasing numbers of aged people projected over the next 50 years. Problems associated with urinary incontinence may be pivotal in determining whether a person is admitted to a nursing home. Indeed, 40%-50% of patients in nursing homes are incontinent of urine (1).

Maintaining dryness in an incontinent patient is often an inexact undertaking. For the ambulatory person, this may be a continual source of embarrassment and may lead to rejection by and isolation from others. For the non-ambulatory patient the continually wetted skin may become macerated with resulting decubitus ulcers and a continuing potential for serious infectious complications (2).

The indwelling urethral catheter has been a venerable but controversial device used in the management of recalcitrant urinary incontinence. A graph of patients by duration of their catheterization would show a bimodal frequency distribution with peaks at 2 to 4 days and at 3 to 6 months or more. The first peak would represent short-term catheterized patients, usually in hospitals and with transient indications for catheterization; the second peak would be composed of long-term catheterized patients, usually in chronic care facilities and with permanent need for urine drainage assistance. Elderly urinary incontinent patients are included in the long-term catheter group. A line at 30 days would divide short-term from long-term catheterization.

Most studies suggest that, once the urethral catheter is in place, the daily incidence of bacteriuria is 5 to 10 per cent per day (3). Calculations indicate that by the end of 30 days the great majority of catheterized patients will be bacteriuric; this is confirmed by clinical observations. Therefore, virtually all patients who are catheterized for months are bacteriuric. Indeed, in those patients who are catheterized for weeks, months, and even years, bacteriuria becomes not only universal but also dynamic and polymicrobial (4). With increasing length of catheterization, in addition to common uropathogens such as E. coli and Klebsiella pneumoniae, less frequent uropathogens such as Providenica stuartii and Morganella morganii become prominent. It is interesting that a wide variety of bacterial species appear to have equivalent assess to the catheterized urinary tract, ie, the incidences of new episodes by different species are very similar. However, once having gained assess to the catheterized urinary tract, bacterial species differ in their ability to persist. For instance, P. stuartii appears to be able to last for weeks and months in the catheterized urinary tract, a feat equaled only by some strains of the well-recognized uropathogen, E. coli. Our studies suggest that this persistence may be related to adherence characteristics of P. stuartii and E. coli, although the specific type of adherence is different between the two species (5).

Consequently, the universal prevalence of bacteriuria in long-term catheterized patients is a function of two related phenomena. The first is a high and equivalent incidence of new episodes of bacteriuria by a variety of bacterial species. The second is the ability of some species to persist in the catheterized urinary tract for very long periods of time. This dynamism results in a polymicrobial bacteriuria, with 75 to 95 per cent of urine specimens containing 2 or more bacterial species, each present in concentrations of 10^5 colony forming units per ml urine. Some specimens contain as many as six or seven separate bacterial species, each present at this high concentration.

Complications of long-term catheterization and bacteriuria in elderly women include local infections, urinary tract stones, vesicoureteral reflux, chronic tubulointeristial nephritis, and renal failure. Our studies have demonstrated that fevers occur in long-term catheterized women but are infrequent and usually low-grade, short-lived, and self-limited. We followed 47 catheterized women for a period of almost 25 patient-years and identified febrile episodes of possible urinary origin as causing about two thirds of the total fevers in these long-term patients. The relatively low incidence of such fevers, 1.1 of 100 patient-days of catheterization, were surprising. Furthermore, most were of a maximal temperature of 102.0°F or less. The total days of fever in these episodes was only 2 per cent of the total patient-days of study. Bacteremias were identified significantly more often when the maximal temperature of the febrile episode was 102.0°F or more. Only 6 per cent of febrile episodes of possible urinary origin were associated with catheter obstruction. This finding suggests that, although catheter obstruction is significantly associated with fever, even complete elimination of catheter obstructions would have minimal impact upon the incidence of fever in these patients.

The unexpected finding of low morbidity associated with long-term urinary catheterization should be tempered, however, by the fact that deaths were associated with some of these febrile episodes. Six of the 47 women died during febrile episodes of possible origin, a number that constituted one half the total deaths from all causes occurring during the study. The incidence of death during fevers of possible urinary origin was 60 times the incidence during afebrile periods. A maximal temperature of 102.0°F was significantly associated with death as it was with bacteremia. These complications of catheterization are among those that are the most easily observed. Our ongiong studies suggest that acute pyelonephritis, chronic tubulointerstitial nephritis, acute and chronic cystitis, and urinary stones also occur in women with long-term catheters in place.Other methods of urinary incontinence management including biofeedback, medications, absorbent products, external collection devices, and innovative surgical procedures such as prosthetic sphincters may be used to avoid the complications of long-term urethral catheters.

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TOWARD AUTOMATIC BLADDER VOLUME CALCULATION

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INTRODUCTION

The extensive use of adult diapers as a means of managing incontinence in long term care facilities reduces the quality of life of many elderly. Often this use is a consequence of staffing economies that obviate the more appropriate management by regular toileting. A non-invasive bladder volume meter might be used to increase the efficiency of the nursing process by avoiding unnecessary effort expended in toileting when the bladder volume is low and by charting bladder volume to enable the scheduling of toileting times.

A number of attempts have been made to calculate bladder volume non-invasively from ultrasound images. Most of these methods involve manually measuring a few major dimensions of the bladder in the images and applying geometric formulae to estimate bladder volume (1,2,3,4,5).

Holmes (6) however took a different approach. His studies showed that "the bladder does not conform to a precise geometric configuration". Bladder shape seems to depend on how full it is as well as a number of other factors. His method involved taking sagittal cross-sectional images at fixed intervals, calculating the area containing urine in each image using a planimeter and then calculating the volume of urine by summing the areas times the distance between images. This method does not require the bladder to have a fixed shape but does require that a person trace the borders. Manual tracing can be accurate, if done by a skilled person, but it is also time consuming.

Beacock et. al. (7) used a method similar to that of Holmes. The differences were that transverse scans were taken instead of sagittal scans, a person outlined the bladder using a joystick, and a computer calculated area and cumulative volume.

It is hypothesized that bladder volume can be calculated non-invasively and automatically by using the following general steps:
1. take a set of ultrasound images of the bladder and digitize,
2. process the images on a computer to obtain an outline of the bladder in each image of the set,
3. calculate the area within each outline,
4. calculate the volume from the areas.

The simplest specific example of using this method is the automation of Holmes' method. Step 1 would involve taking a set of parallel sagittal ultrasound images of the bladder. Steps 2 and 3 would be as stated and step 4 would involve taking the sum of the areas calculated in step 3 times the distance between scans.

Step 2 of this process is complicated by the fact that different portions of the edge of the bladder in trans-abdominal ultrasound scans are represented in different ways. The anterior portion of the bladder wall generally appears as a bright line but can be difficult to differentiate from other bright lines which appear in the same area, many of which are artifacts. The posterior portion of the bladder appears clearly due to the difference between the dark (anechoic) urine and the bright tissue region behind it. The inferior portion of the bladder cannot usually be seen because it is posterior to the symphysis pubis which blocks the ultrasound. The superior portion of the bladder wall can sometimes be seen as a change from dark urine to brighter tissue but often the tissue does not appear.

In this paper, we describe work completed to develop software to extract the bladder outline, i.e. step 2 of the generalized process.

METHOD

Our method of outlining the bladder in ultrasound images (8) involves two main steps. First standard image processing techniques are used to highlight the edge of the bladder. Then a "bladder wall follower" is applied to the processed image to give an estimate of the outline of the bladder.

Combinations of edge detectors and thresholders can be used to highlight the parts of the edge of the bladder which can be seen by a human but large portions of the edge of the bladder cannot be seen. As well, this image processing highlights areas other than the bladder wall.

A bladder wall follower was developed to fill in the gaps left in the outline after the image processing, and to differentiate between highlighted areas which represent the edge of the bladder and those that do not. The bladder wall follower is a line follower with rules. These rules consist of conditions for deciding if the follower is on the bladder wall as well as directions for how to get back if it has strayed. There are sets of conditions and directions for each of the regions where the processed images are expected to be inadequate due to the nature of the ultrasound images.

The programs developed were tested on images of three healthy subjects. Midline scans for each of the subjects were analyzed as well as the right lateral most scans of two of the subjects.

RESULTS

The outlines produced were similar to those indicated by the ultrasound technician when the images were taken. Figure 1 shows an example of an outline obtained (white line) overlayed on the original ultrasound image. The image in this figure is a sagittal midline scan of a healthy female subject. Note that the inferior portion of the outline is not included in this image but at present we estimate this portion by a straight line.

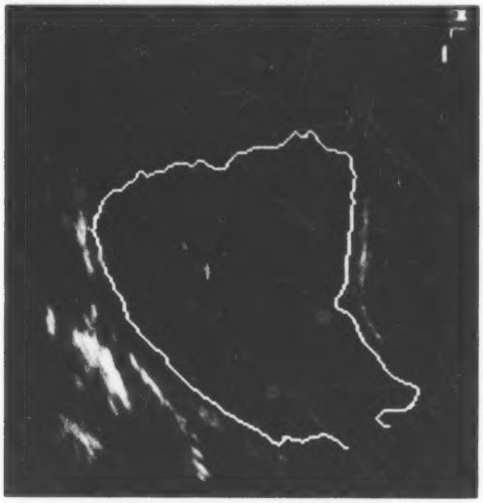

Figure 1: Bladder outline in sagittal midline scan

DISCUSSION

The purpose of our current work is to show that bladder volume can be calculated automatically and non-invasively from ultrasound images. In order to achieve this goal, the automation of Holmes' method will be completed. Included in this work will be verification of the accuracy of the bladder outliner by obtaining and analyzing images of other subjects. It is expected that the system may fail for some images but that deficiencies can be corrected by adjusting the rules for the bladder wall follower or by adding new rules. Software for steps 3 and 4 of the process will then be written and calculated volumes will be compared with voided volumes.

Further work will include deciding on the optimal set of image planes to use (e.g. not necessarily parallel sagittal planes), investigating whether it is possible to pre-define ultrasound imaging system settings so that the need for user adjustments can be avoided, and ways of speeding up the digital processing.

The eventual goal is to develop a dedicated ultrasound bladder volume calculator which would, optimally, be hand held.

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TECHNOLOGICAL CONSIDERATIONS IN DEVELOPMENT OF EXTERNAL URINE INCONTINENCE DEVICES FOR WOMEN

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The lack of external urine incontinence devices for women is not due to a lack of interest. Edwards (1) found that ancient Egyptian papyrus writings made reference to their use. Female devices were often occlusive in nature and designed as a gold phallus-type structure which was placed intra-vaginally and probably relieved stress incontinence. Hippocrates suggested inserting a finger into the vagina to support a defective bladder neck mechanism and thus prevent incontinence (1). Continuous wear devices were probably not considered until rubber was manufactured. This paper will examine technological considerations in development of an external urine incontinence device(EUID) for women.

An EUID device should be simple to apply, easy to clean, made of material that is non-irritating, rugged and odorless. Materials to make EUID are available in medical grade forms of latex and silicone. These materials clean well, are durable, and have the potential for multiple applications which increases its cost effectiveness. Ease of application is influenced by ability to locate the urinary meatus, and separate the legs. Early EUID's were in the shape of a wide necked rubber funnel which completely enclosed the vulva and were firmly attached to the body with a support belt (2). The Hollister Female Urinary Incontinence Pouch (3) is similar since it encompasses the vulva. Other devices have given women specific directions for application between the labia to surround the urethra, i.e., FEMEX (4) and MISSTIIQUE EUC system (5). EUIDs which are placed between the labia do require some lower limb mobility for proper placement. Some inventors have attached a vaginal locator to the device to assist location of the meatus and stabilize the device.

An EUID should be suitable for both day and night use as well as bedfast, sedentary, or active women. Urovac (7) was a suction operated device which was placed over the labia majora and was restricted for bed use. Similarly, Crowley, et al (8) introduced a device that used suction to produce a seal between the device's urinary drainage opening and the tissue around the urethra. Literature and patents of devices not attached to suction machinery claim use for bedfast or ambulatory women.

An EUID should fit women of different body builds and genital development which raises a major question as to the configuration of the female external genitalia, i.e. size and dimensions of the labia and location of the meatus in reference to the vaginal opening and clitoris. What changes occur to these measurements with aging and pregancy? The MISSTIQUE EUC is available in two sizes. Some EUIDs were made in one size but excess material may be trimmed from them before application (3,4).

The EUID should be light weight, produce little awareness of its presence, and result in no undo pressure on the perineum. Generally, EUIDs have this quality. The weight of the urine collection bag pulling on the EUID is a greater concern.

The EUID should result in few complications from its use. Complications primarily refer to tissue irritation, vaginal irritation or infection, and urinary tract infection. Tissue irritation may develop from the adhesive or suction used to adhere the EUID. Vaginal irritation or infection may develop from use of a vaginal locator or the device covering the vaginal opening. Microorganisms enclosed by the device may attribute to UTIs.

Most important, the EUID should be leak proof and allow continence while wearing it. Statistics on continence control for EUIDs are difficult to obtain and do vary (5,6,8).

The patent process and new product engineering must be considered for any technological development since both are costly and time consuming. Patents for EUIDs may be more difficult to obtain due to previous patents in that category. Patent laws vary among countries. Manufacturing of a new product means machinery must be developed, research performed and marketing strategies initiated. To stimulate technological innovations, the U.S. has a Small Business Innovation Research Program (SBIR). One area of interest of the SBIR program is urinary incontinence.

In summary, a literature search and U.S. patent search identified several EUIDs for women. Devices differ in use of a vaginal locator, adhesive, suction, support belt, potential length of wear, size and mobility with use. Marketability of devices has varied. Further research and development of EUIDs is needed especially in adherence products, wearability in women of a variety of ages and activity levels, effectiveness and safety. Probably several EUIDs will be available for women in the near future. Such devices may provide women with a treatment and cost alternative for urinary incontinence.

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THE BENEFITS AND COSTS OF REHABILITATION TECHNOLOGY: ETHICAL AND POLICY CONSIDERATIONS

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The entire health-care enterprise, which has thus far focused on acute illness and cure, is now having to face the fact that many aspects of our system are no longer in phase with the on-going care needs of an ever increasing segment of the population: those in need of rehabilitative care. Hospitals are designed to provide acute care, and physicians are oriented around the concept of "curing" people and sending them home. Yet this often results in a mismatch of acute-care services and continuing care needs.

In recent years, a great deal has been written in the policy and economics literature about benefit-cost analysis and cost-effectiveness analysis applied to health care of the elderly and disabled. Some rather remarkable ideas have been put forward that are becoming more and more attractive for some analysts and decision makers in the health-care sector.

The first was the concept of human capital, which suggests that it is appropriate to look at the health-care system as a factory whose product is well people. It follows that if we could simply bring the rationality of the factory into the health-care workplace, we could achieve the great economies and efficiencies that, we are told, Detroit has achieved over the years in making cars.

With that image in mind, human-capital proponents pointed out that if you run a car factory and want to know if you should throw out or repair a particular machine that makes speedometers, for instance, you could call in your managers and ask them several questions. "What will it cost us to buy a new speedometer-making machine, and what will it cost us to fix the old one? How many new speedometers will this new machine make and how many will we be able to make with the old one if we repair it?" Then you simply tally up the plusses and the minuses and make a rational decision.

If you make cars, that is probably an appropriate way to operate. But it is disturbing to note the frequency with which this kind of analysis is being applied to rehabilitation and health-care economies. If we conceptualize people as entities that produce wealth for the economy, we can measure how much someone contributes to the gross national product. By tallying up how many dollars an individual would contribute to the economy based on future life expectancy and productivity, and measuring that against how many dollars it would cost to fix that person, it is argued we could rationally decide whether it's economically "worth it" to repair a given patient.

Of course, the elderly and disabled are at risk of coming up short in this kind of analysis. If you are seventy years old, by definition you are going to have fewer years ahead of you than does someone who is twelve. It would then follow that one could tell a sixty-five or seventy-year-old person (who may have been forced to retire), "Sorry, you're no longer a productive member of our society, so we're going to spend fewer dollars on your care." That kind of benefit-cost analysis is rather horrifying. Rashi Fein, a medical economist at Harvard, put it succinctly. "We don't live in an economy; we live in a society." There is a big difference between the two.

A further extension of the human-capital approach, called the net livelihood method, measures how many dollars people draw out of the economy as well as how many they contribute. With this method, some people will even have a negative net-livelihood, which means that they are allegedly drawing more dollars from the system than they are putting into it. If one's goal is to maximize the gross national product, it is obvious that the only thing to do with those people would be to let them die as quickly as possible.

Other policy analysts prefer the approach of cost effectiveness and, at least initially, that concept sounds more attractive. It avoids conceptualizing people as factories that should be shut down if they don't generate enough dollars. Rather, this method measures how many years of life can be saved by a given health-care intervention such as renal dialysis, an immunization program, or prenatal care for pregnant women. But, here too, there is a problem. It is highly unlikely that any intervention will ever save as many years of life for someone in his sixties as for a pregnant women in her twenties. Again, the numbers are simply stacked against the elderly.

The cost-effectiveness approach gets even worse, in my view, with the "refinement" known as quality-adjusted life years. Advocates of this view claim that different years of life have different worth, and should be valued differently. If a patient is chronically ill and has a major impairment, a year of life would be worth less than a year of healthy life in decisions about how many years can be saved by a given intervention. A proponent of this approach might argue, "If we look at the number of quality-adjusted life years, there is not a lot of mileage in taking care of old sick people, because our equations tell us that if you have arthritis and heart disease and a little bit of Alzheimer's, then really a year of your life is worth only about 4.5 weeks." Those numbers are then compared against what we are spending on the elderly, and it becomes clear that the elderly are "getting more than their appropriate share of the health-care dollar." What follows then is usually a series of recommendations that advise us not to spend too many resources for such a meager return.

That phrase — "appropriate share of the health-care dollar" — is rather curious. Health care is for people who are sick. Sicker people need more health care than a healthy person. The idea that everybody ought to be getting the same amout of health care, whatever their age and whatever their illness, may seem to some to be democratic. But a few milliseconds of reflection reveals that it is profoundly wrong.

We are in a bind. Increasingly, we are told by our colleagues in economics that we need to begin to act like real businesspeople and introduce some of the rationality of the factory into the hospital. It is certainly true that the health-care system has been more than a little sloppy in its spending over the last twenty years. Before DRGs somebody always paid the bill, even if a procedure wasn't altogether useful. Now, as we try to educate providers about such things, one of the major challenges in academic medicine is to figure out how to communicate to physician trainees and other health professionals an understanding that money is not infinite, without inculcating the idea that the bottom line is more important than the patient. It is very difficult to make sure that students clearly pick up the right message. In fact, we are now beginning to hear some statements on rounds like, "Well, are the number of quality-adjusted life years going to be worth the cost of this intervention?" That kind of reasoning is flawed. The patient's best interest should be the only basis for our decisions. Yet we need to learn a lot more about how providers, patients, and families can work together to determine when enough is enough. At what point should we be able to talk with the patient and family and say, "It is in no one's interest for this care to continue"?

There are two ways to approach this problem. First, a society can say, as in Great Britain, "We do not dialyze people over the age of fifty-five or sixty." If you are over fifty-five in Great Britain and you have renal failure, you will probably be told, "Sorry, we don't have a treatment for you. Your condition is terminal."

Of course, we all know that there is a treatment. The country has simply made a societal decision not to provide dialysis to the elderly. Discussions of dialysis in Great Britain often neglect to mention that dialysis for the elderly is not illegal; it is simply that the National Health Service does not pay for it. I doubt that many affluent elderly patients, who are otherwise well, die of renal failure in Great Britain. They just buy their own machine. It is critical to bear in mind that rationing, particularly by age, is rarely rationing just by age. It is rationing by age and economic status.

Here in the United States, we are not about to go back on our decision to dialyze all who need it. But we are moving rapidly into a position where we will find ourselves telling older patients, "If Medicare doesn't pay for all of it, you've simply got to pay out of pocket, or come and see me privately." As we revert closer to the old pre-Medicare system, we will begin to see more and more of this. Is returning to a two-class system of health care the only way we can contain health-care costs?

I believe that more intelligent, accurate clinical decision-making could both enhance the quality of care and contain costs, particularly in the care of the elderly. An additional approach would engender a greater sensitivity on the part of physicians, patients, families, nurses, and hospital administrators in confronting whether it is truly in a patient's interest to prolong his or her terminal care. In the outpatient setting, I have seen many elderly patients who have told me, "I never want to be put on all those machines. I've lived a long life. When I get that sick, I just want to be allowed to die quickly and peacefully." Then when an illness occurs, as it always does, they are admitted to the emergency room, and immediately the whole, enormous system kicks into action. In many, many cases, we impose a lot of terribly expensive care on individuals who really don't want it.

We need to figure out how to empower patients while they are of sound mind, if not of sound body, to indicate through a variety of mechanisms what kind of care they want at the end of life. And we need to provide it to them. In many respects, we are now performing a disservice to some patients by imposing on them far more care than they ever would have wanted. It is not doing them any good; it is not doing the families any good; it is not doing the health-care system any good.

The ideal is for such decisions to be made by the patients, themselves, whenever possible. The most attractive mechanism seems to be the concept of durable power of attorney, in which the patients stipulate who will have the legal authority to indicate their treatment preferences when they are not able to do so. We must develop an active nationwide effort to achieve a greater level of sophistication on all fronts concerning this kind of personal decision-making about health care. We should aim for a day when the majority of patients coming into an emergency room will have a pre-existing arrangement stipulating, in a legally acceptable way, whom they have chosen to voice their preferences in decisions about their care. In this way, all of us in the health-care endeavor can get out from under our fear of litigation and other distracting constraints that often impel us to do everything to everybody all the time, even when the patients we are treating would not have wanted it that way. This will protect the dignity and the rights of our patients. It will allow us to better focus our energies on those who do want all available interventions. And, by the way, it would save hundreds of millions of dollars each year.

It will be crucial that we guard carefully against such an approach occurring in a way that would not empower our older patients, but would rather deprive them of autonomy. Should a patient indicate that he does want what interns call "the full court press," we must not say, "Well, he's eighty-five years old, it's not worth the cost." The world of difference between these two approaches must not get confused in the public mind or in ours.

Tough times lie ahead for all of us as we try to grapple with these issues, particularly if we try to keep the welfare of the elderly patient at the top of our agenda. Of course we must do that, not only because it's the right thing to do, but because the elderly segment of the population is the one disadvantaged group that all of us are likely to enter, ourselves, one day. We don't all become black, we don't all become poor, and we don't all become women. But we do all become elderly if we live long enough. To paraphrase Pogo, we have met the elderly, and they are us. It is our own future, as well as that of our parents and grandparents, that we are shaping.

ETHICAL CONSIDERATIONS IN REHABILITATION OF THE ELDERLY

Nancy Neveloff Dubler, LL.B.

Most elderly persons live in the community. At some time in the aging or dying process however many will circle through an acute care hospital. A few will enter long-term care institutions, in which they will most likely die. At some point in their lives, given patterns of chronic disease many will need rehabilitation counseling and support.

Many caregivers assume that elderly persons have diminished abilities to weigh risks and benefits and therefore to decide according to their own best interests. Some of this bias is based on fact--more elderly persons are afflicted with cognitive disorders or with dementias than are younger persons (3). Yet even in those elderly who are cognitively clear, other behaviors may be interpreted as diminished ability: problems with ambulation or speech projection are often misapprehended as disturbances of thought and judgment. A slowly moving, slowly speaking older person is likely to frustrate a faster moving younger person and thereby be dismissed as an intellectual inferior.

Chronic illness and chronic pain may effect the elderly person's perception of interventions. Many, desperate for relief will agree to any suggested course of treatment. Some, despondent at repeated failures, will initially reject even promising new approaches.

Particular problems surround those elderly who need rehabilitation for physical and speech deficits. These persons may be perceived as decisionally impaired because of communication disabilities which may be separate and distinct from any deficits of cognition and judgment. Those whose bodies are locked-in place can never display the affect and provide the emphasis available to the well-bodied. Those with speech problems are at a far greater disadvantage. We assume that speech reflects thought. We react to hesitant, halting, disorganized presentations as if they emanate from a disordered intellect. For certain disabled elderly this reaction is counter to reality.
It requires patience and understanding to sort out relevant information from physical noise and static when dealing with certain disabled elderly. This inability to communicate clearly and directly does not necessarily, although it may, indicate decisional incapacity. It requires penetrating to the source of decision to determine whether a patient is capable of functioning. If the patient can consider options,the situation demands that caregivers present the patient with all of the information required as the basis for an informed consent dialogue and engage the patient in the process of choice. This process will be time consuming and frustrating for physician and patient alike, but is morally and legally mandatory.

The rights of these patients, never secure in fact although much supported in theory, are subjected to new threats in this third decade of the development of patient protections and patient's rights (1), (2), (4), (5). Prospective payment mechanisms which now apply to Medicare reimbursement appear to change the grounding of the doctor/patient relationship by introducing factors into the care of a patient which are not necessarily congruent with the patient's stated wishes or the physician's notions of best interest. Techniques of analyses and concepts developed to address legal and ethical dilemmas which surround treatment decisions are inadequate to these new issues. Concepts such as informed consent and the right to refuse care are useful in mediating between physician suggestion and patient desire; they become marginal in the face of systemically imposed solutions. Supposedly mandated discharge plans stand in some splendid isolation both to patient and physician. The sometimes absurd theater of discharge decisions includes a greater number of individual and institutional actors acting out "Becket-like" scenarios in chaotic stage sets.

During hospitalization a number of options for care will be presented to the patient for acceptance, modifications or rejection. In the end a plan must be made for post-hospital care. How many branches on the decision tree will be traced depends on the difficulty of the differential diagnosis, the perceived immediacy and urgency of the decision, the personality, training and character of the attending physician, the courage of the staff and the philosophy of the hospital administration. The range of options will be affected by the services available in the community, and the position of the patient and family. The real, perceived or assumed mental status of the patient, the availability and aggressiveness of family or other surrogates and advocates, and the judgment of caregivers regarding the appropriate discharge plans will determine which choice is made. In this schema it is of course much easier for caregivers to decide about and impose treatment interventions than to implement plans for rehabilitation. The former requires hospital staff action--the latter, patient cooperation and an effective support network.

Choices about rehabilitation present similarities to and contrasts with other sorts of decisions about care. These decisions are similar in that they require a patient to assimilate the diagnosis and prognosis, consider the alternative treatments, and the risks and benefits of those treatments and impose an individual intellectual and emotional calculus on this raw data to reach an appropriate personal decision. They are different because they require ongoing cooperation which demands a continuity of focus and resolve. In effect a decision to accept or to reject an offered rehabilitation intervention is composed of a series of little decisions, sometimes made daily, or hourly to cooperate and struggle with a rehabilitation plan. In the context of rehabilitation consent and refusal are a process, not an event.

Competence or Capacity

The principle which determines whether the patient or another decides is competence. The law is clear: "Every human being of adult years and sound mind has a right to determine what shall be done with his own body." (7). The fulcrum concept is that of "sound mind," an issue often discussed under the topic of competency, but more properly addressed by asking if one possesses the requisite capacity to make decisions. Competence is a legal presumption which attaches at the age of majority and which can only be overturned by a court. Decisional capacity is a patient characteristic consistently measured by caregivers in both episodic and ongoing relationships which determines whether the patients will be included in or excluded from decisions surrounding their care (5), (6). Judgment about competence also reflects certain assumptions and perceptions about the human condition. For example, it incorporates our collective understanding that small children and infants lack the skill, wisdom, experience and intellect to make weighty decisions, for they are unable to think abstractly, to project consequences and to accept present burden for future benefit. Children are thus categorically incompetent. This decision of society reflects perceived patterns of human development.

The word, "competence," therefore refers to a melange of societal judgments and caregiver evaluations; it is both a normative and descriptive term; it both encompasses the unchanging perceptions and psychological verities of the human condition, and reflects fluctuating societal values which are based on contemporary needs (e.g. employment patterns, and military conscription). As a societal artifact, the concept of competence may reflect society's timebound needs to include or exclude persons from full participation in the community of deciders.

In a work which has helped to form and reflects moral consensus, the President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research (6) viewed decisional capacity as consisting of three elements:

(1) possession of a set of values and goals;

(2) the ability to communicate and to understand information; and

(3) the ability to reason and to deliberate about one's choices (President's Commission, 1982).

This formulation presents a very rigorous standard.

Emerging from the discussion above are two distinct but largely overlapping senses of competence:

1) It is a synonym for what society or caregivers will allow people to do, in different settings, at different stages of life and

2) It is a set of intellectual and psychological capacities that are necessary for informed judgment, i.e. which permit subordinating the autonomous designs of an individual to the judgment, and action of others.

Given the range of included meanings for the term, "competence,: it is no wonder that confusion is the norm rather than an occasional occurrence. If one adds this conceptual unclarity to the biases about the elderly previously discussed, in the context of impersonal institutional care, it should not be surprising that those elderly who can decide are often ignored and those who cannot decide may be abandoned. The former occurs when a decisionally capable individual is bypassed and decisions about care requested from a surrogate. The latter describes the situation which exists when a patient not capable of deciding either appears to nod agreement to a suggested plan or does not vigorously protest. Non-protestation is probably an insufficient basis for rehabilitation. It will not provide the motivation for cooperation, effort and struggle.

Issues of consent to or refusal of a rehabilitation plan by an elderly patient are surround by complex medical, psycho-social determinants. They require an elderly person to consider the options and choose that plan which most suits personal needs.
Within this schema many elderly might choose the continuation of disability. They may be afraid of failure or of the pain and effort demanded. They may be resigned to disability or actually receive some secondary benefit from the condition. They may be dependent on caregivers and on the life-style the disability has created. They may be tired, or discouraged, or resigned. They may misunderstand the suggested intervention and the demands it will make.

Caregivers must evaluate all refusals to ensure that, to the greatest extent possible, choices are made based on evaluation and preference, not misunderstanding and fear. They must inform, and cajole and encourage, but not intimidate or frighten. They must respect rights while they value feelings

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